NPS

AD-A240 648

Nonpoint Pollution Discharge Permit Testing and Control Strategies at Naval Air Station Whidbey Island

by Kevin G. Vogelsang

A non-thesis paper submitted in partial fulfillment of the requirements for the degree of

Master of Science in Civil Engineering

University of Washington
Department of Civil Engineering

1991

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The purpose of this study was to analyze systematically a nonpoint storm water monitoring program at Naval Air Station Whidbey Island, Washington, to determine if more relevant data can be obtained at lower cost by revising the sampling location, frequency, or pollutants of interest. Current remedial investigations of contaminated sediments, station hazardous material use information and station management plans provided the bulk of the data.

Watershed review indicated that potential contamination by 26 compounds may be present in the storm runoff. Testing to identify the presence of these compounds is required to renew an existing National Pollution Discharge Elimination System permit for the air station. It was also found that the frequency of sampling could be reduced from 52 events per year to about 30 with no significant loss of statistical accuracy, thereby reducing the recurring cost of the sampling program.

Also discussed are management practices and structural improvements that are technically feasible for controlling the two most significant pollutants, oil and grease and suspended solids. Best Management Practices are recommended to prevent or clean the spill of aviation fuel at the spill location. Use of synthetic oil-sorbent booms is recommended in lieu of the existing baffle treatment system.

ACKNOWLEDGMENTS

The author wishes to acknowledge the support and direction provided by the following people:

Richard Horner, Brian Mar, and Eugene Welch of the University of Washington Department of Civil Engineering.

The many people at NAS Whidbey Island who took the time to discuss how they work, especially Kathy Souders and Diana Tener of the Environmental Affairs Office.

Andrea Lindsay of the U.S. EPA NPDES Permitting Section, Region 10, Seattle.

Patty, Audrey and Patrick Vogelsang.

1.0 INTRODUCTION

This paper researches the requirements and recommends a testing program for renewal of the existing National Pollution Discharge Elimination System (NPDES) permit for non-point pollution discharge at Naval Air Station (NAS) Whidbey Island, Washington. Regulations resulting from the 1987 Water Quality Act require revisions to the enforcement sampling frequency and the reconnaissance testing of additional pollutants. This paper provides a qualitative assessment of the NAS Whidbey Island watershed in an effort to identify those pollutants that may be present in the storm discharge from this industrial activity and to identify an appropriate sampling location so testing is performed to find the potential contaminants at the least cost. Finally, the paper discusses treatment alternatives to remove the storm water pollutants which are most likely to require continued monitoring in order to comply with the renewed permit. If pollution abatement systems are needed to remove these monitored pollutants, design work can then be directed to the best treatment alternative.

There has been a significant amount of research on pollutant concentrations in highway storm runoff. However, no published work was found which addressed the routine pollutant loadings of an airport. The determination of potential pollutants was complicated by the discharge of storm runoff through this site, which is on the Superfund National Priority List. While this paper is very site-specific, much of the data and methodology can be applied to other airport or transportation facilities. For instance, the determination of which storm water pollutants may be present is primarily a function of current and past hazardous material usage, and the pollutants' affinity to soil particles, volatility and persistence in the water/soil environment. Many of the on-site pollutants at NAS Whidbey are common at other transportation facilities, since most are constituents of petroleum fuels or carried by suspended solids.

The problem of runoff pollution control at airports is not unique to NAS Whidbey Island. Several Navy-owned facilities on the West Coast, including NAS North Island, NAS Moffett Field, NAS Alameda and MCAS Camp Pendleton, are built in areas with high ground water elevations and must take special spill control precautions. McChord Air Force Base, also permitted for oil and grease discharges, has an oil/water separator and skimmer system installed on their runway drainage system. Additions to Albuquerque International Airport in 1987 included special provisions for isolating fuel spills within the storm drain system (Robinson, 1988). Also, the recent terminal addition to Toronto's

Lester B. Pearson International Airport includes two storm drain systems to isolate fuel spills and aircraft deicers from the storm flows (Prendergast, 1991).

The approach taken in this paper is based on the premise that spilled contaminants reach and are carried by the storm runoff. Because it is usually easier and less expensive to prevent a spill than to clean one up, several possibilities for local containment of a fuel spill, which is the most likely continuing contaminant source, are also provided. The in-depth coverage of spill control, however, is already being addressed by others at the air station and is not the focus of this project.

1.1 Background

The 1972 amendments to the Federal Water Pollution Control Act, now known as the Clean Water Act (CWA), prohibited the discharge of pollutants to waterways unless the discharger had obtained a NPDES permit (Federal Register, November 16, 1990). Originally intended to control industrial process and municipal wastewater outlet pipe releases, it became apparent in the late 1970s that "nonpoint" or diffuse storm water runoff was a major contributor to water quality degradation. From 1978 to 1983, the U. S. Environmental Protection Agency (USEPA) funded a series of studies under the Nationwide Urban Runoff Program (NURP) which were intended to characterize the quality of storm water runoff. The NURP studies found that annual loadings of suspended solids from storm sewers were two orders of magnitude higher than secondary wastewater treatment plants, and annual chemical oxygen demand (COD) measurements from the two sources were essentially the same. Tests of residential, commercial and light industrial runoff identified 77 of 120 priority pollutants, with 24 of the pollutants present in more than 10% of all samples (Federal Register, November 16, 1990).

When the Water Quality Act of 1987 was passed by Congress as an amendment to the CWA, the law included wording specifically intended to address the problem of nonpoint discharges. Section 402(p) was added to the CWA, which now mandates NPDES permits prior to 1 October 1992 for storm water releases from currently permitted dischargers, municipalities with populations greater than 100,000, and most industrial activities. Transportation facilities, including airports, are considered industrial activities pursuant to the section 402 of the CWA (Federal Register, November 16, 1990).

A NPDES permit establishes a limit on the quantity of a pollutant that can legally be discharged into the nation's waterways. The permit holder must test the effluent at intervals specified in the permit and report test results to the regulatory agency that issued the permit. NAS Whidbey Island, Washington, reports its test results to USEPA Region 10 in Seattle, Washington.

NAS Whidbey Island has three permitted discharges. This paper will only deal with the discharge permit for storm water runoff which is pumped or passes a tide gate into Dugualla Bay. The other two existing permits are for domestic sewage treatment plant discharges. Most of the storm runoff from aircraft taxiways and runways flows into an unlined drainage ditch, joining storm runoff from much of the developed area of the base, which flows into a stilling basin before discharge to the tidal waters of Dugualla Bay.

Station records indicate that in 1990, over 8,000 gallons of JP-4 and JP-5 aviation fuel were spilled during refueling, flight line operations, or fuel tank expansion venting. The fuel that did not volatilize was flushed into the storm drains as a fire prevention measure. Previous waste disposal into the ditches has resulted in their listing on the USEPA's Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) National Priority List. (Actual funding for site cleanup is from the Department of Defense Environmental Restoration Account, but procedural requirements are essentially the same as CERCLA's.) During storm events, contaminated sediments may be released into the storm flow, possibly resulting in the contamination of Dugualla Bay.

Updated permit renewal regulations for nonpoint sources were published in the 16 November 1990 Federal Register in response to the Water Quality Act of 1987. The existing station permit expires in 1992 and these new regulations will require modifications to the current sampling routine as part of the permit renewal. In addition, the continuing contamination of a National Priority List site complicates the ongoing Remedial Investigation and exposes the Navy to unnecessary liability risks.

1.2 NAS Whidbey Island Development

Whidbey Island is located in Puget Sound northwest of Seattle, Washington. The 65 mile long island varies from one to ten miles wide. The town of Oak Harbor at the northern end of the island borders the naval station. The western side of the island is defined by the Strait of Juan de Fuca and Admiralty Inlet. The eastern coast is bordered by

Dugualla and Skagit Bays, Saratoga Passage, and Possession Sound. Agriculture and forested lands dominate the island's land use (NEESA, 1984).

NAS Whidbey Island was commissioned for military service in September, 1942. It is actually two bases, known as Ault Field and the Seaplane Base, located five miles apart on either side of Oak Harbor. This paper focuses on the larger of the two bases, Ault Field, which contains most of the military activities.

Ault Field comprises 4,339 acres and is bordered by the Strait of Juan de Fuca on the west and rural or agricultural communities on the other three sides. Whidbey Island is home to several active duty squadrons that fly the A-6 attack aircraft, several reserve units, and supporting units. Over 6,000 military personnel plus dependents and 1,300 civilians are stationed at the air station (NEESA, 1984).

Major facilities at Ault Field include two 8,000 foot runways with associated taxiways, aprons, hangers and tower; administrative, medical, dental, messing, berthing, family housing, shopping, recreation, and hobby facilities; fuel transfer, fire protection, wastewater treatment, shops, landfills and other public works type facilities. About 763 acres are leased to local farmers for agricultural use. Primary crops are broccoli, cauliflower, root stocks and grasses. Cattle grazing is presently conducted on one leased parcel. Most of the air station buildings are located at the southern end of the base, and the flight line and runways are in the northern end.

Ault Field has four "nonpoint" or storm water discharges and one domestic sewage treatment plant "point" discharge. The current air station NPDES permit includes the sewage treatment plant which discharges to the Strait of Juan de Fuca, a treatment plant discharge from the Seaplane Base into Crescent Harbor, and the unlined storm water drainage ditch within the airfield which discharges into Dugualla Bay. The other three storm discharges are into the Strait of Juan de Fuca. While it may seem unusual that one nonpoint discharge is currently permitted, this is consistent with the definition of the CWA when one considers that the Dugualla Bay discharge, identified as outfall 003, often requires pumping and has a treatment system consisting of a series of three baffles. It is essentially a regulated industrial discharge and has been operating under a NPDES permit since 1979. In fact, any discharge through a pipe or constructed channel is a point discharge. The failure to regulate most storm outlets as point sources was due to the USEPA's limited administrative capabilities and the lack of technical data on the extent of the problem (Griffin, *et al.*, 1991). A group permit is being pursued for the three remaining storm outfalls, and they are not included in the scope of this paper. Discharges that are currently permitted can not be added to a group permit. Therefore, the existing permit for oil and grease discharge from the runway ditches, outfall 003, must be renewed prior to its May, 1992 expiration.

1.3 Current Permit Procedures

A grab sample is collected from the middle of the drainage ditch every Sunday by the base maintenance contractor and analyzed for pH and oil and grease by a private, USEPA certified laboratory (Tener, 1991). The requirement for weekly sampling and the appropriateness of the tested pollutant are central issues that must be addressed by the new permit. There is no correlation of sampling frequency or timing to spill events or to storm events. Current discharge limits for oil and grease are 10 mg/L average per month and 15 mg/L daily maximum, and pH must be between 6 and 9 at all times. Table 1 provides a summary of the reported discharge values for calendar year 1990. These values have remained consistent over the length of the permit.

Monthly maximum and average test results are submitted to the USEPA with an approximation of the weekly flow rate. The quantity of flow is determined by dividing the weekly outfall pump meter reading by seven to obtain a daily average and then corrected to account for an assumed base flow (Tener, 1991). The reported flow value does not represent an estimate of the flow at the time of sampling, but an average flow for the week that the sample was collected.

The permit presently requires sampling at the point of discharge to Dugualla Bay, although the sample is actually collected prior to the third baffle, a point approximately 5,200 channel feet before the storm water leaves the air station and approximately 10,400 feet upstream of the location listed in the permit. Sampling at the point identified in the current permit would include sampling of agricultural and rural runoff from areas the Navy does not own. Pollutants from farm operations, a local roadway, rural residences or a sand and gravel quarry could enter the runoff after it leaves the air station but before discharge, requiring the Navy to identify and report pollutants over which it has no control. Figure 1 provides a topographic view of the air station, with the storm drainage ditches, watershed, sampling and discharge locations identified.

Table 1. Reported Runway Ditch Effluent Discharge Values for 1990.

Month	pH (units)		Oil & Grease (mg/L)		Flow (MGD)	Samples (#/mo)
	Min	Max	Avg	Max	Avg	
January	7.4	7.6	1.2	5.0	0.31	5
February	7.3	7.5	1.1	2.4	0.28	4
March	7.3	7.4	0.5	0.5	0.25	4
April	7.3	7.4	1.0	2.2	0.24	5
May	7.3	7.5	0.7	1.2	0.14	4
June	7.3	7.3	0.5	0.6	0.20	4
July	7.1	7.4	0.7	1.1	0.07	4
August	7.0	7.1	1.2	2.2	0.12	4
September	7.1	7.3	0.8	1.7	0.12	4
October	6.9	7.1	0.7	0.8	0.15	4
November	6.8	7.1	0.6	0.6	0.59	4
December	7.0	7.2	0.8	1.5	0.35	5
Averages	7.2	7.3	0.8	1.7	0.24	
Standard Deviation	0.2	0.2	0.3	1.2	0.14	
Permit	6.0	9.0	10.0	15.0		

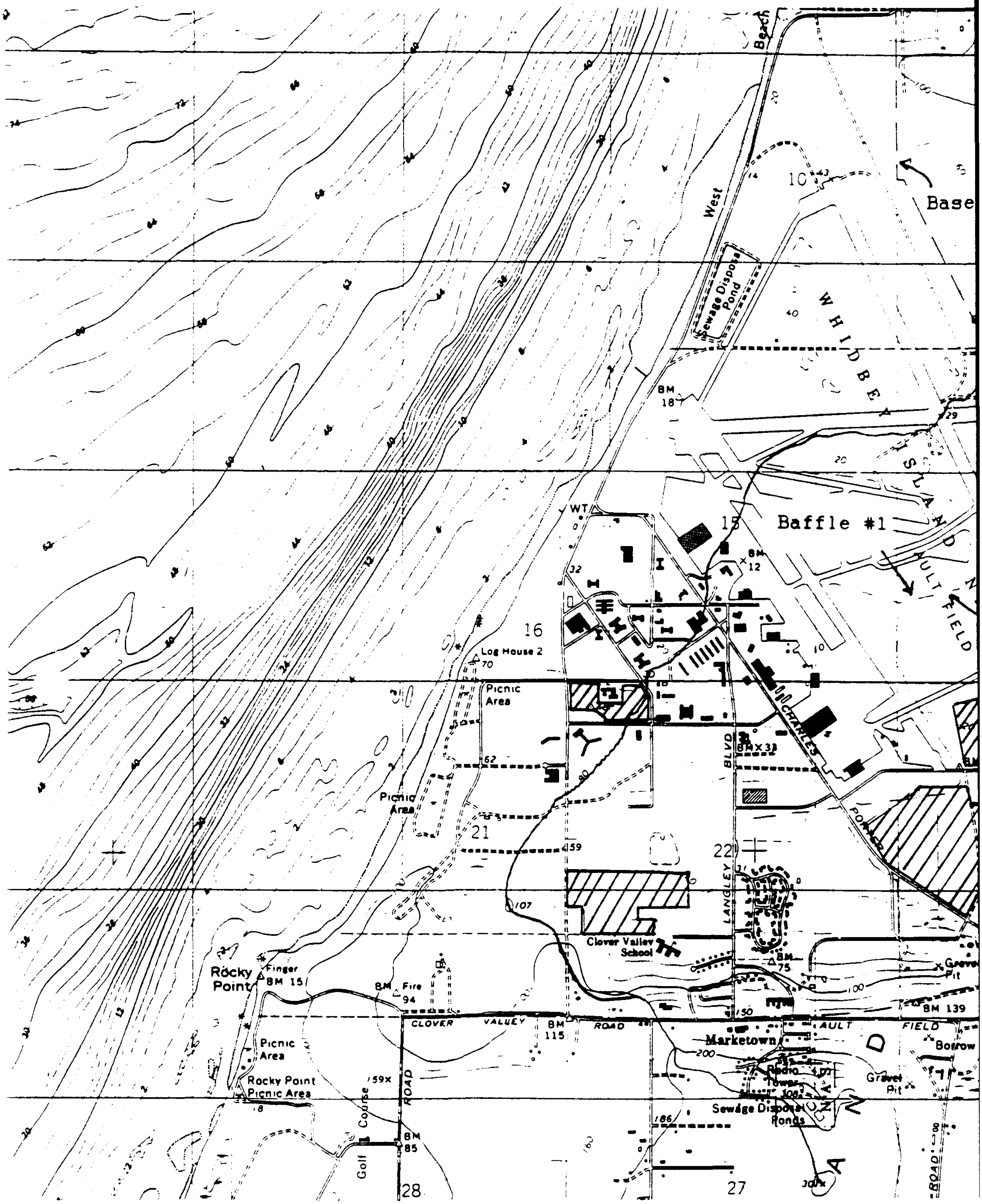
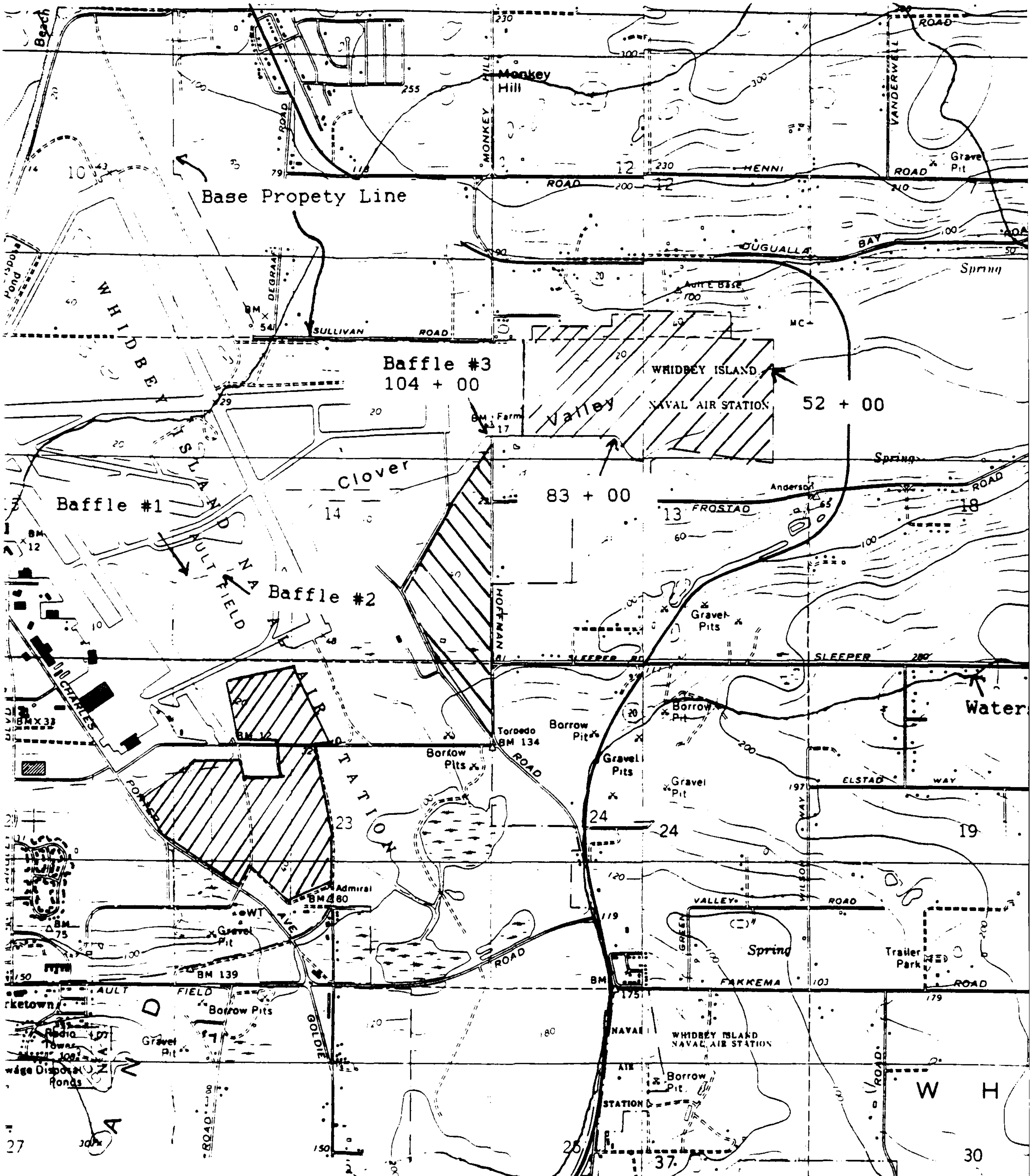


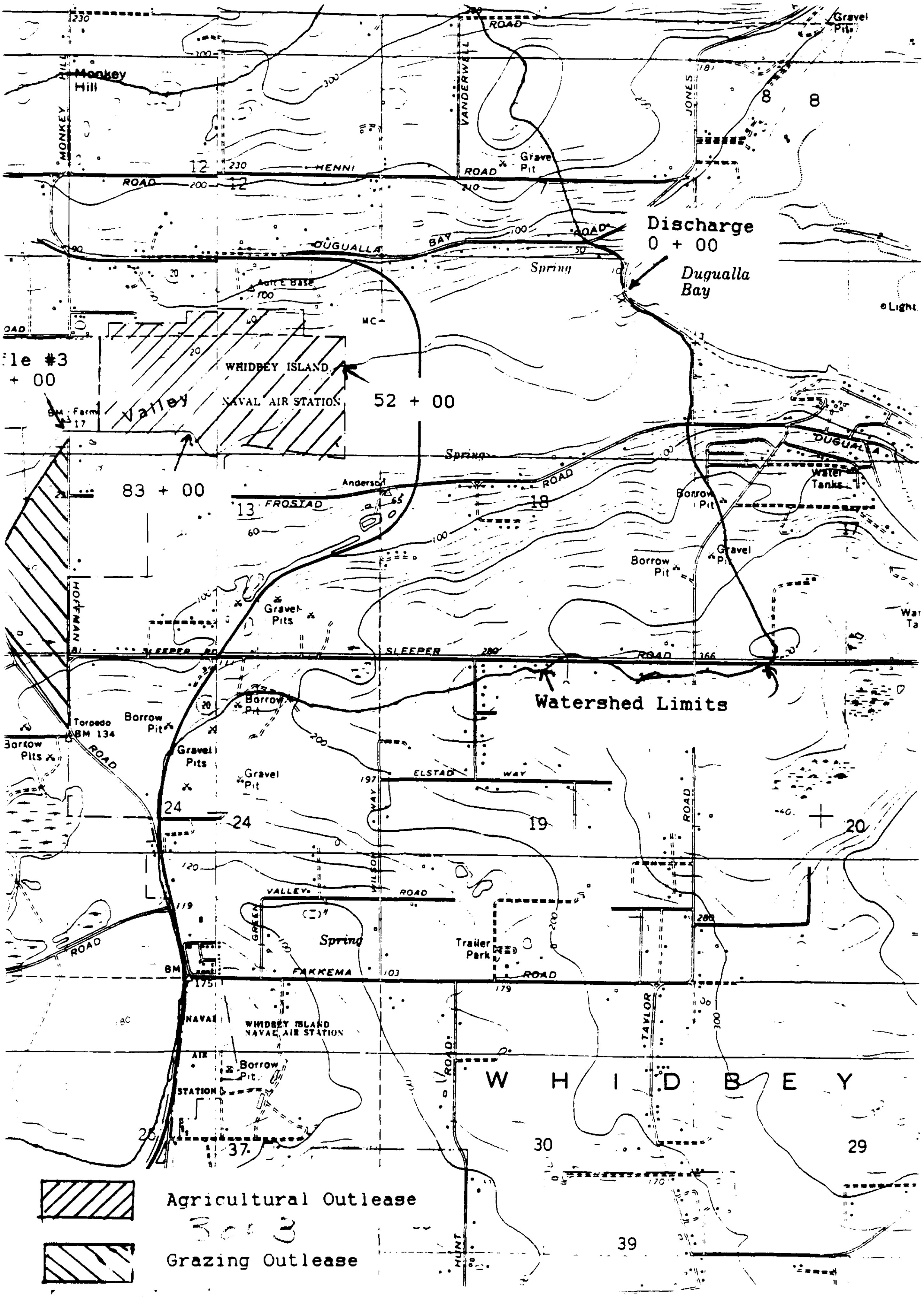
Figure 1. Topographic Map of Ault Field. Watershed, drainage ditch channel stations, agricultural outlease areas and discharge are identified. Scale: 1 inch = 2,000 feet. Source: U. S. Geological Survey, Denver, Colorado.



. Watershed, drain-
outlease areas and
= 2,000 feet.
Colorado.

Agricultural Outlease

Grazing Outlease



Discharge
0 + 00
Duguala
Bay
52 + 00
83 + 00
Watershed Limits
WHIDBEY ISLAND
NAVAL AIR STATION
Valley
Monkey Hill
HENNI ROAD
DUGUALLA BAY ROAD
FROSTAD
SLEEPER ROAD
ELSTAD WAY
VALLEY ROAD
FAKKEMA ROAD
HOFFMAN ROAD
TAYLOR ROAD
HUNT ROAD
WILSON WAY
VANDERWELL ROAD
JONES
Spring
Gravel Pits
Borrow Pit
Water Tanks
Trailer Park
Anderson
W H I D B E Y
Agricultural Outlease
Grazing Outlease

1.4 Site Characteristics

1.4.1 Physical characteristics

The naval station has six identified ecosystems: mixed evergreen forest, brush and grassland, freshwater wetland, saltwater marsh, beach and coastal zone and agricultural. The storm ditches and airfield area are dominated by seasonal freshwater wetlands, with poor drainage throughout the winter and spring and dryness in the summer and fall (NEESA, 1984).

A wide variety of wildlife exists, including a great blue heron rookery, and the naval station serves as foraging areas for the American peregrine falcon and bald eagle (U. S. Soil Conservation Service, 1991). The risk of biological accumulation of contaminants in these foraging species is a primary area of concern that is being evaluated as part of the Superfund Remedial Investigation.

The climate consists of cool, wet winters and warm dry summers. Average annual rainfall is just under 20 inches in the vicinity of the air station, ranging from 0.71 inches average in July to 2.8 average rainfall in December. Average monthly temperatures fluctuate from 39^{0}F in January to 60^{0}F in August, with a yearly average of about 49^{0}F (NEESA, 1984). Very cold or very warm temperatures are rare and do not normally last for extended periods. Snowfall is minimal and usually melts within a few days; however, the necessity to maintain flight capabilities requires the use of deicing salts for brief periods each year.

Rainfall and storm intensity data are summarized for the period 1984-1989 in Table 2. The Appendix provides a month-by-month summary for the same period. This time span, though short, includes both very wet and very dry years. The "Qualifying Event" represents a 24-hour rainfall of at least 0.10 inches that occurs 72 hours after the previously recorded "Qualifying Event". The number of events is an approximation based on daily rainfall data reported by the National Oceanic and Atmospheric Administration from a non-recording rain gauge at the Coupeville, Washington, weather station. Data from a recording rain gauge are not available. The number of qualifying events is essential in determining the frequency of testing under the new permit requirements.

Table 2. Rainfall Event Summary for 1984 through 1989.

Year	Precip (in)	>0.1 in (days)	>0.5 in (days)	Qualifying Events
1984	25.66	71	12	33
1985	16.34	63	4	29
1986	17.05	58	5	32
1987	13.22	40	3	22
1988	18.11	62	7	29
1989	20.57	66	9	31

Source: National Climatological Data Service, National Oceanic and Atmospheric Administration.

The runways sit in a low-lying valley that ranges in elevation from 10 to 50 feet above sea level. The land slopes gradually upward to 100 feet on the northern end and 150 feet on the southern end of the naval station. Ground surface elevations when the storm water leaves the base are below sea level.

The geology of the island is typical for that of the Puget Sound. Fine-grained silts cover harder silts, which in turn cover many heterogeneous layers of sand, clay, silt and gravel deposited by repeated glacial action. The air-field soils around the drainage ditches are generally wet and poorly drained. They have been classified by the U. S. Soil Conservation Service primarily as Bellingham silt loam and Carbondale muck. Both soil types exhibit very limited infiltrative capacities and approximately 75% of rainfall becomes surface runoff (U. S. Soil Conservation Service, 1991). Soil types in the vicinity of the air station drainage ditches are available in the air station's Natural Resources Management Plan.

Although the air station imports its potable water via pipeline from the east, groundwater is a primary water source for most Whidbey Island residents. The sea level aquifer has been classified as a sole source aquifer by the USEPA (Federal Register, April 6, 1987). Groundwater is encountered at a depth of only 0 to 15 feet in the low-lying air station areas. The drainage ditches generally have water in them all year long. The depth of the ditches averages about eight feet, indicating that they provide a groundwater discharge area. It is not clear if they provide a recharge area during wet winter months, but it seems unlikely. The high water table in the grass fields of the runway infield should provide adequate lateral pressure in the poorly drained soils to maintain a positive pressure gradient in the direction of the cut face of the drainage ditch. The presence of perched water tables is common on Whidbey Island (U. S. Soil Conservation Service, 1991) and it is possible that only a perched water table is releasing to the drainage ditches. This would not significantly change the nature of the problem, since any contaminated recharge could still exist in the sole-source aquifer due to the lack of an extensive confining layer.

1.4.2 Runoff Quantities

The exact amount of discharge into Dugualla Bay is not known, since there is no flow meter on the tide gate structure. The pump capacity is 6,000 gallons per minute, but records on the number of hours the pump operated do not distinguish between base flow and storm flow, since tidal fluctuation also influences pump operation time. The Dugualla Bay outfall drains approximately 3,380 acres of watershed, or 78% of the total air station (Tener, 1991). The grass and weed covered infield contributes between 0.8 and 7.2 inches of runoff per year. The 725 impervious acres contribute an average of 9.5 inches of runoff per year. Total air station runoff is estimated at 420 million gallons by the U. S. Soil Conservation Service (1991). With 78% of the drainage area, outfall 003 should account for approximately 327 million gallons annually. However, the compliance reports submitted to the USEPA indicate only about 85 million gallons were discharged in the twelve month period between March 1990 and February 1991. This would indicate that approximately 75% of all drainage ditch flows pass the tidal gate and only 25% is pumped. Unfortunately, the lack of a recording flow meter makes it impossible to verify this discharge.

The channels are typically filled with bulrushes and cattails along the sides and bottom. This vegetation, and any exposed soil, are visibly stained before the first oil/water separation baffle, as can be seen in Figure 2. Minor staining is present at the second baffle, and no staining is visible at the third baffle. The lack of obvious staining at the points where the storm drains first go through the transition to surface ditches indicates that the baffles generally perform as expected: they back up floatable product until it is collected by pumper truck.

The main drainage ditch, which is generally 30 to 40 feet wide and eight feet deep, has been known to fill completely during prolonged, severe storms. This situation occurred as recently as November, 1990 (Tener, 1991). Side slopes are cut as steeply as 1.5:1, with 2:1 tapers near the top of the channel. With a typical gradient slope of 0.003 the two 60-inch, 200-foot long concrete pipes at the outflow from the last baffle can easily accommodate a peak average flow of over 800 gallons per minute. The calculation is only an approximation, since groundwater discharge and back pressure from the stilling basin, the elevation of which is a function of the tide stage, can affect the flow rate. The storm flow data and drainage system hydraulic capacity are being reviewed by Sajan, Inc., Seattle.

Figure 2. Visible Soil Staining at First Baffle.

1.4.3 Existing Baffle Operation

The runway drainage ditches receive aviation fuel spills which are washed off of the parking apron and into the storm drains to minimize the risk of fire. A series of three baffles, installed in the 1970s, is used to skim floatable free product from the surface of the drainage ditches. The first baffle, shown in Figure 3, consists of a concrete diversion structure with a fixed elevation steel baffle for a skimmer. At most flows, the steel baffle stops floatables and forces water to flow beneath the baffle. At very large flows, the excess water spills over the baffles. The other two baffles are constructed of treated lumber and operate in the same manner.

The presence of floatable product behind the skimmers is visually checked by contractor maintenance workers weekly and removed with suction equipment, if possible. Occasionally, free product can not be recovered because winds blow the floating product upstream from the baffle. Final disposal is in accordance with Resource Conservation and Recovery Act requirements. Table 3 presents a summary of oily waste collected and disposed of during 1990. About 90% of the total volume of 4950 gallons is water. In addition, two 55-gallon drums of contaminated vegetation, 400 pounds total, were also disposed of as hazardous waste.

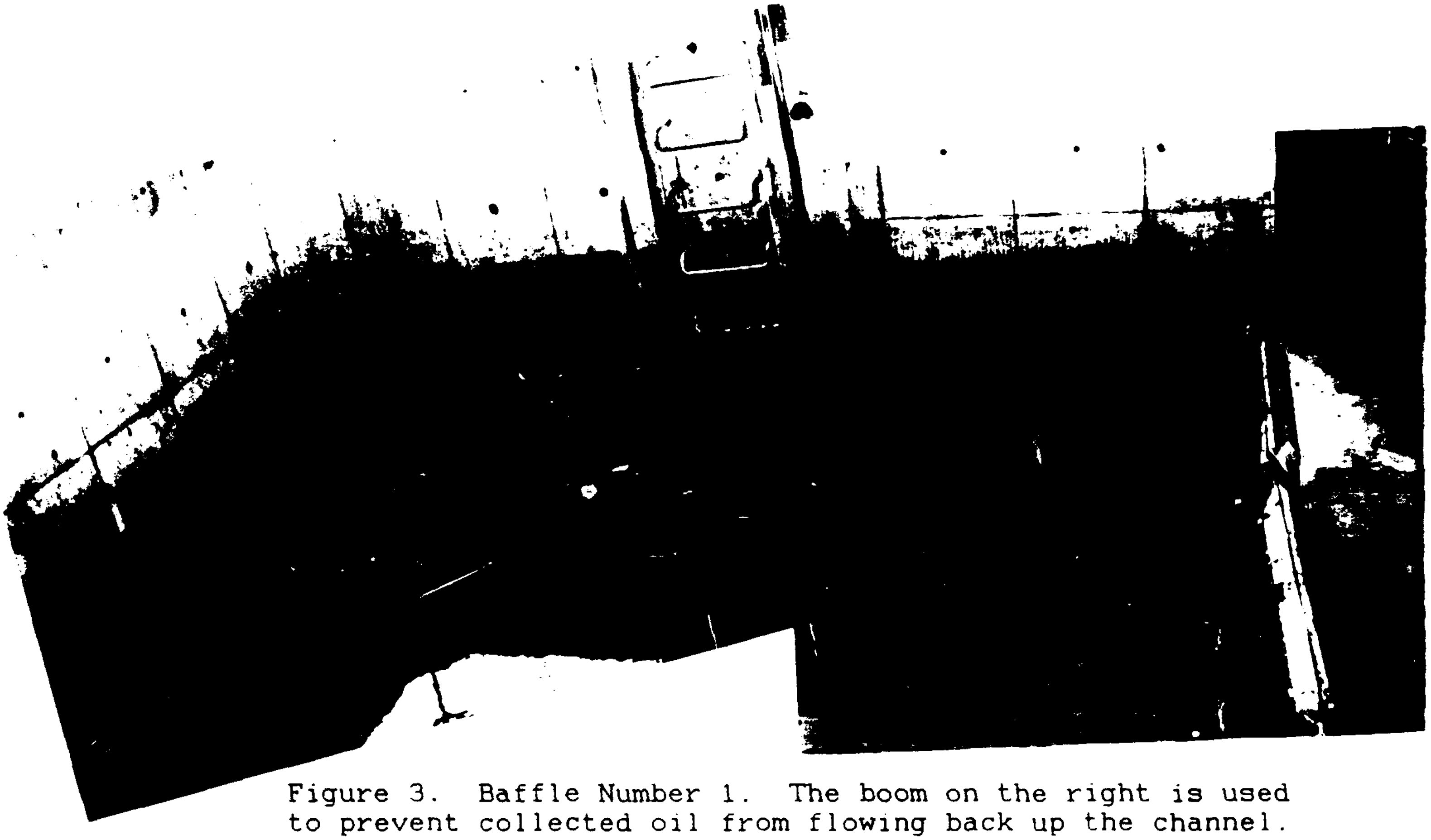


Figure 3. Baffle Number 1. The boom on the right is used to prevent collected oil from flowing back up the channel.

Table 3. Oily Waste Collection at Baffles for 1990.

Month	Quantity (Gallons)
January	600
February	1,000
March	550
April	750
May	0
June	400
July	300
August	100
September	850
October	0
November	400
December	0
Total	4,950

Fuel content estimated to be 10% of total collected.

Source: Tener, 1991.

1.5 Descriptional Monitoring Programs

There are several methods one could use to monitor the drainage ditch discharge and identify the potential pollutants. If an unlimited budget were available, continuous sampling of all 225 CWA contaminants could be pursued. Obviously, the significance of much of the data would be minimal, since many of the pollutants may not be present in the discharge continuously or at every level of discharge. In addition, certain contaminants may have a more significant impact at high water levels than low, or when temperature is at a given level, or during the breeding season of a sensitive species. This natural variability can result in the requirement to collect and analyze many samples in order to determine a statistical mean.

Two methods can be used to minimize the amount of natural variability in sample data to make results more useful. If a period of special concern for a given pollutant can be identified, then the monitoring can be performed only during the period of interest. Then, detecting a change in contaminant concentration can be determined with a reasonable degree of certainty and for minimum cost. This is known as stratifying the samples (Mar, *et al.*, 1986).

The other approach is to collect composite samples of the flow, which will reduce fluctuations and allow a more accurate determination of total loadings with fewer samples (Mar, *et al.*, 1986). The new nonpoint regulations, by requiring sampling only of "qualifying event" storms and composite sample analyses of most pollutants, are attempting to minimize natural variability and improve usefulness of the collected data.

In order to meet the goals of identifying the location and frequency of monitoring, a systematic approach to identifying which contaminants to monitor must be pursued. A descriptional monitoring program has been developed by Reinelt, *et al.* (1988) which can be used to identify the sources of pollutants and the relative change to receiving water quality from multiple sources. One must identify a problem and define the monitoring objectives, conduct a watershed analysis to identify the sources and quantity of pollutants, evaluate alternative sampling programs to satisfy the objectives, and then rank the alternatives. This procedure, discussed below, was followed in this paper at a very qualitative level. However, with this being the first assessment of the air station runoff, a more detailed review may be necessary.

A descriptional monitoring program objective could be to establish background levels or existing conditions (reconnaissance monitoring), to identify a change in conditions over time (ambient monitoring), or enforcement monitoring to identify permit violators. The USEPA's permit enforcement monitoring requirement establishes the objective for this paper. The objective can be met with variable levels of detail, and an initial records review may indicate whether additional detail is required.

Once the object of monitoring has been identified, watershed analysis is conducted to identify potential pollutant loadings based on land use and critical watershed areas. This may involve use of various soil loss and pollutant loading simulation models, or just a qualitative assessment. The completed watershed analysis should allow one to identify the areas or problem pollutants around which to build the monitoring program. The sampling program should satisfy the objective in the most cost-effective and statistically valid method.

A sampling program which indicates a change when a change has not occurred commits a Type I error. A testing regime that indicates no change in an effluent when a pollutant load has really changed commits a Type II error (Mar, *et al.*, 1987). Regulatory agencies are greatly concerned with minimizing the chance of Type II errors, and therefore tend to commit Type I errors. A good monitoring program would avoid both errors.

The probability of avoiding a Type I error is known as the confidence level and is independent of the size of the change predicted. If the standard deviation is large for the item of interest, then many samples will be required to provide a high confidence level. The probability of avoiding a Type II error is known as the power, and depends on the predicted size of the change between two means, or Delta. If a large change is anticipated, the power increases for the same number of samples (Mar, *et al.*, 1987). Detecting a change is important when assessing the impact of a new treatment plant or revised management practices. Stratifying a sample, so that like populations are compared, may reduce the number of samples in each group but increase the confidence in the mean, thereby improving the chance of observing a change with a smaller Delta.

Although the required testing frequencies for this project are dictated by law, a computer program will be used to assess the validity of the necessary sampling program at NAS Whidbey Island and compare it to the current sampling protocol.

A descriptional monitoring program concludes with a ranking of the different sampling routines that are possible to meet the objectives, so decisions can be made based on the value desired from the testing program. If additional data are later obtained, the program can be reassessed based on the new information and any necessary adjustments can be made to the monitoring program.

1.6 Problem Statement and Objectives

This project explores the premise that a systematic analysis of a monitoring program can produce a monitoring program that will deliver more relevant and useful information, reduce the costs of monitoring, or both. A qualitative analysis of watershed sources and contaminant transport will be conducted to accomplish four goals:

a. Identify the pollutants which may be present in the storm water discharge due to the past or present use of hazardous materials.

b. Select an appropriate sampling location to resolve the current discrepancy between the location cited in the existing permit and the current sampling location. The selected location must be appropriate for identifying the pollutants which may be present in the storm discharge.

c. Identify the frequency of sampling required and the statistical relevance of the selected frequency.

d. Identify treatment alternatives for removing the most probable pollutants from the storm discharge.

2.0 METHODS

This project prepares a qualitative watershed analysis by assembling and assessing the data available from many different sources. The selected research methods emphasize this point.

2.1 Initial Assessment Study

The Navy's initial response under the Department of Defense Installation Restoration Program, which was similar to CERCLA, was to create the Navy Assessment and Control of Installation Pollutants (NACIP) Program. This program, under the direction of the Naval Energy and Environmental Support Activity, evaluated every Navy activity for evidence of contamination that may pose a threat to human health or the environment and prepared an Initial Assessment Study (IAS) for each activity. The Initial Assessment Study (NEESA, 1984) provides the summary of the archive and preliminary visit findings.

2.2 Current Situation Report

The Current Situation Report (SCS Engineers, 1988) was prepared as a follow-up to the IAS to identify contamination sites which required a Remedial Investigation - Feasibility Study (RI/FS). Some physical surface water, groundwater and soil sampling was performed at the sites by SCS Engineers, and samples were analyzed to confirm pollutant presence and identify those sites which required an RI/FS. Sampling data in this report were used extensively in identifying the pollutants of interest.

2.3 Site Visits and Personal Interviews

Three site visits were made to NAS Whidbey Island to review station permit, Superfund, and waste disposal records, walk the length of the drainage ditches, photograph baffles, and observe flight line operations. Personal interviews of air station, engineering, USEPA, test laboratory, maintenance contractor, suppliers and farmer personnel were conducted in person and by telephone. Questions were designed to identify waste or hazardous material handling and usage procedures, baffle operational procedures, and testing protocol requirements. Various station management plans were reviewed, often while in the process of being revised.

2.4 Computer Evaluation of Monitoring Program

Using the PC-based DESIGN program (Palmer and MacKenzie, 1985), the power of some alternative test frequencies was determined. DESIGN allows the analysis of the tradeoffs in a testing program: more samples yield more data, but the value of the data do not increase linearly. The DESIGN algorithm is a valuable tool for maximizing the value of data from a fixed budget or for maximizing the statistical power of a sampling program by determining the most cost-effective number of sampling stations and replicates for a given number of sampling occasions. The program requires information or assumptions on the overhead and direct costs of testing and collecting a sample, measurement and collection errors, expected magnitude of change (Delta), number of control sites, number of seasons, and number of sampling occasions. Sensitivity analysis allows one to investigate quickly where the most significant and cost-effective parameter changes can be made to achieve specific testing goals. Assumptions for this paper are based on the discussions with testing laboratories, literature review and engineering judgement.

2.5 Determining Pollutants of Interest

In determining which pollutants to analyze, consideration was given to the requirements published in the USEPA's final rule, the contaminants found in runoff studies of other transportation facilities, the Navy's use of hazardous materials and the biological, chemical and physical properties of the compounds.

There has not been significant research conducted to identify the pollutants from an airport. Several studies of highway runoff quality have been conducted, however. Asplund (1980) found that highway runoff quality was greatly affected by rain patterns (frequency, intensity and duration), traffic volume, surrounding land use, local geology, maintenance procedures, and the drainage system design. Chui, *et al.* (1982) developed a model useful for predicting annual loads from traffic volume, local land use and runoff coefficients after sampling over 400 storms in the Pacific northwest. Martin (1988) quantified runoff quality from a Florida bridge as part of his evaluation of detention pond effectiveness.

Although these studies do not apply directly to airport facilities, they do give a good indication of the pollutants that may be present in the runway runoff due to the inherent similarities of transportation facilities. The airport will have less total solids, since deposition from the aircraft is minimal (airplanes are kept scrupulously clean when compared to automobiles and trucks). Litter and debris are also kept to a minimum to avoid the risk of engine damage. However, the likelihood of finding similar fuels, cleaning materials, rubber and metal compounds is high. At NAS Whidbey Island, the runoff from roads and the developed area could be a substantial contributor to the pollutant load in the drainage ditch discharge.

In developing the list of pollutants that may be present, consideration of the desorption of contaminants from the soil, solubility and volatility of the contaminant, degradability of the contaminant, and channel erodability must also be considered. Channel erodability will be considered first.

2.5.1 Channel Erosion

The potential for channel erosion at Whidbey Island appears to be minimal. In fact, the generally slow flow velocity within the channel results in deposition of sediments that must be dredged periodically to maintain the channel flow capacity. There is no physical evidence to suggest that channel erosion during high water results in increased suspended solids in the discharge. This is not to say that suspended solids discharge does not increase during a storm, because the recently deposited sediments can be resuspended during increased flow periods, eventually increasing suspended solids discharge during or shortly after the storm event.

2.5.2 Contaminant Degradability

Contaminant degradability in the strictest sense is a function of a pollutants ability to be broken down by chemical reactions, light or microorganisms into less toxic or non-toxic by-products. This paper evaluates each pollutant in slightly more general terms: is it persistent in the environment? Those compounds which are more susceptible to degradation by aerobic or anaerobic bacteria, ultraviolet radiation, or chemical oxidation will be less likely to be released in future storm events, as long as the sources of new contamination have been eliminated and conditions favor their degradation. This paper assumes that the major continuing sources of contamination from the airfield are fuel spills, wash rack compounds and deicing salts. Other past disposal practices have been corrected. Other possible sources of toxic or hazardous compounds would be the result of improper storm water controls during remediation at Superfund sites within the Ault Field watershed which drain through this discharge, general urban runoff, or the agricultural outlease areas.

The presence in soil of large numbers of bacteria capable of degrading most organic compounds is ubiquitous (Ghiorse and Balkwill, 1983). Flowing water in the shallow drainage ditches may maintain aerobic conditions, but the saturated soils and sediments may remain anaerobic for most of the year. Therefore, anaerobic decomposition potential may be of major significance. Biodegradation may not occur, however, if other factors needed for bacterial growth are not present. In any event, the potential for degradation of the soil contaminants discovered during preliminary site characterization will be discussed.

2.5.3 Contaminant Solubility and Volatility

Solubility of the compound measures the propensity of a pure product to become homogeneously mixed with water. High solubility constants indicate a compound is more likely to dissolve into the water matrix, and less soluble compounds are more likely to remain as free product. The presence of oil product complicates the determination of solubility. For example, compounds with a high octanol-water partition coefficient (K_{ow}) are less likely to dissolve into water from an oil film (Southworth, *et al.*, 1983).

A volatile contaminant will be less likely to show up in measurable quantities in the discharge, because of vaporization as the flow mixes on its way to the discharge (Rathbun and Tai, 1982). While volatilization of a pollutant only results in its transfer from liquid to gaseous phase, not its removal from the environment, the knowledge of phase transfer is important when determining potential for storm water discharge. The Henry's constant of a compound represents the ratio of gas phase to liquid phase of the compound under given temperature and pressure. Compounds with high Henry's constants are more likely to volatilize.

2.5.4 Partitioning to Solids

The tendency for a product to adsorb to or desorb from soil particles can be approximated by the K_{ow}, the soil's organic carbon content, density and porosity (Wu and Gschwend, 1986). These effects can be synergistic. Data are not available on the carbon content of the soil in the drainage ditches, so relative tendencies of pollutant behavior are discussed in this paper.

3.0 RESULTS

3.1 Renewal Application Requirements

The current permit for the discharge of oil and grease under the National Pollution Discharge Elimination System will expire in May, 1992. The renewal application must be submitted by October 1991.

The new regulations require sampling of industrial facility storm water discharges for as many as 225 pollutants. The specific pollutants of interest at NAS Whidbey Island will be discussed later. The rule generally requires testing for any of the pollutants listed in Tables 2F-1 through 2F-4 of the regulation which the discharger knows or has reason to believe may be present in the discharge in concentrations greater than 10 parts per billion (ppb), although there are a few exceptions to the 10 ppb concentration. In addition, there are eight mandatory analyses (oil and grease, biochemical oxygen demand, chemical oxygen demand, total suspended solids, total Kjeldahl nitrogen, nitrate-plus-nitrite nitrogen, total phosphorus and pH) which must be performed by all industrial activities as a result of the findings of the NURP studies. Identifying pollutants present in the air station storm discharge that are on these lists is the primary goal of initial sampling.

Grab samples collected in the first 30 minutes of a storm, or as soon as practicable thereafter, and flow weighted composite samples collected over the entire storm or for at least the first three hours of the event must be tested. A storm event is defined as rainfall greater than 0.1 inch in 24 hours occurring at least 72 hours from the previous event. The regulation also recommends the duration and rainfall variance not exceed 50% of the average event in the watershed.

There are other permit requirements for storm water discharge associated with industrial activity besides completion of the appropriate forms and submittal of test results. A topographic and site drainage map must be submitted. The site drainage map must include a narrative description addressing: the existing structural and non-structural (maintenance) controls; materials used, disposed and stored and the methods of transport, storage and disposal; description of material loading and unloading; location and frequency of pesticide and herbicide use; soil description; and the areas responsible for the first flush.

The permitting agency is the USEPA, but the recently adopted 1991 Puget Sound Water Quality Management Plan requires the state Department of Ecology to review existing federal facility permits for wetland compliance (PSWQA, 1990). The USEPA must also follow state regulations for nonpoint sources, and will provide an opportunity for the state to review the draft proposal and USEPA response (Lindsay, 1991). Total maximum daily loads are used for nonpoint sources in Washington State (Griffin, *et al.*, 1991) but specific discharge limits will be set on a permit-by-permit basis.

3.2 Test Frequency

Test frequency under the new law is related to the number of storm events. As demonstrated in Table 2, there are about 30 qualifying storm events per year. Testing on a storm event basis will eliminate the requirement for weekly sampling and should reduce the number of sampling events by 22 per year. The renewed permit may, however, demand continued weekly testing if adequate management practices and structural controls are not in place. Results of a statistical analysis of alternative test frequencies are provided in section 3.5.

3.3 Pollutant History

In 1990, 8,799 gallons of aviation fuel, primarily JP-4, was reported as spilled. A summary of fuel spill events is provided in Table 4. Large spills are classified as those over 25 gallons. This distinction is based on the supposition that small spills can be cleaned up quickly and easily with absorbents. Spills over 25 gallons are too large for portable, self-contained sorbents, and require a centralized spill team response. Recall that fuel recovered at the baffles over the same period, shown in Table 3, was less than 500 gallons, or 5% of the quantity spilled.

Table 4. Aviation Fuel Spill Summary for Calendar Year 1990.

Month	Large Spill Volume (Gallons)	Large Spill Events	Small Spill Volume (Gallons)	Small Spill Events
January	270	8	180	23
February	235	4	280	37
March	105	3	322	30
April	810	10	293	30
May	340	11	554	58
June	370	6	396	43
July	235	4	483	56
August	375	10	489	63
September	645	11	461	54
October	390	8	238	26
November	758	4	256	28
December	240	4	74	14
Total	4,773	83	4,026	462
Avg/Month	398	7	335	38

Source: Schurr, 1991

Besides receiving this recently spilled fuel, the drainage ditches have been identified as site 55-16 in the ongoing Superfund Remedial Investigation underway on the air station's National Priority List sites. According to the January 1988 Current Situation Report:

> "An estimated 30,000 to 50,000 gallons total of JP-5 was discharged to this site between 1965 and 1974. Prior to 1965, an estimated 5,000 to 10,000 gallons per year of AVGAS was spilled along the flight line and washed into storm drains or drainage ditches. From 1965 to 1981, as much as 600 to 700 gallons of waste cleaning solvents and 2,000 to 3,000 gallons of caustic rinsate containing phenols, cadmium and chromium in a basic solution, were discharged to the storm sewers annually from Hanger 6. In the 1960's and 1970's, as much as 5,000 gallons of waste motor oil and 1,000 gallons of waste solvents, paints, strippers, and thinners, may have been discharged each year to the storm sewers by the ground equipment maintenance shop. Steam cleaning and paint spray booth wastewater was

also reportedly discharged to the storm drains in the 1970's." (SCS Engineers, 1988, p. 3-49.)

Table 5 summarizes the results of composite soil and sediment samples conducted on the drainage ditches during March 1987 as reported in the Current Situation Report. The sampling locations are indicated on Figure 4. Aliquots and duplicates indicate that laboratory analytical errors and collection errors are minimal, with the exception of total organic halogens (TOX). For these compounds detection limits were essentially too high to be very useful, because of the high hydrocarbon content. Two separate composites were prepared at each sampling location except CS6. Four composites were prepared for location CS6. Background samples were collected at sites CB1 and CB2, and dredged drainage ditch sediments were sampled as SD1. Table 5 provides the mean and standard deviation of the reported values, which represents an approximation of the natural variability.

The soil/sediment sampling data identified elevated petroleum hydrocarbon concentrations at almost every location, with the highest concentrations at baffle 1 (CS3) and the two main flight line storm sewer discharge locations (CS2 and CS4). Elevated metals, especially arsenic, were found at CS4 and CS7, and other sites had lead levels higher than background.

Currently, wastewater from an aircraft wash rack is being routed through the storm drains. Cleaning fluids used on the wash rack include an aromatic petroleum hydrocarbon-based solvent for oily areas on an aircraft and a compound containing dipropylene glycol methyl ether, alkylaryl ethoxylate and capric acid diethanolamide for general purpose cleaning. There is a project scheduled to connect the wash rack drainage to the domestic sewer system, so wash rack wastewater is treated before discharge. In addition, ethylene glycol is used as an aircraft deicing fluid if flight operations are necessary during very cold weather. Two hundred gallons of ethylene glycol were used during a two-week period at the end of December, 1990.

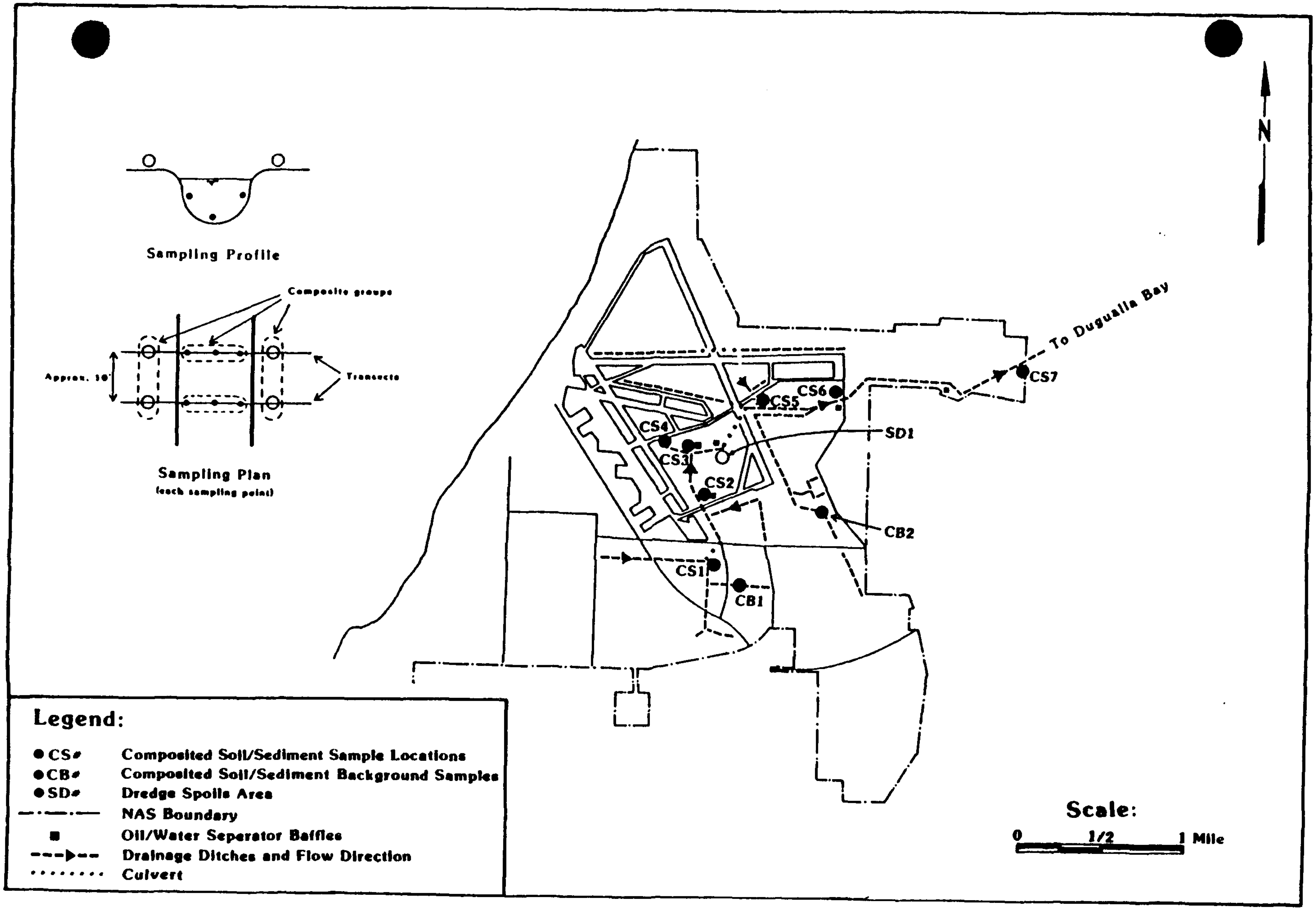


Figure 4. Drainage Ditch Soil/Sediment Sampling Locations.

Source: SCS Engineers, 1988.

Table 5. Runway Ditch Soil/Sediment Sample Results.

Sample Location	CS1	CS1	CS2	CS2
Sample Type	Sed	Soil	Sed	Soil
Fuel Scan				
Petroleum Hydrocarbons	100	200	8000	130
Total Solids	40.7+ 6.6	35.6+ 8.9	71.2+ 1.3	75.4+ 3.2
Total Organic Halogen (TOX)	18 + 3	21 + 5	9.8 + .2	18 + 8
Metals				
Arsenic	42 + 5	37 + 1	6.5 + .1	7.6 + 1.6
Barium	87 + 6	110 + 14	56 + 16	76 + 16
Cadmium	.21 + .08	.43 +.16	2.7 + 2.	2.3 + 2.7
Chromium	32 + 10	33 + 15	49 + 13	23 + 2
Copper	26 + 10	39 + 6	28 + 13	17 + 3
Lead	3.6 + 1.1	8.2 + 4.0	47 + 33	17 + 19
Mercury	<.03 + 0	5.5 + 7.7	.04 +.02	.04 +.02
Nickel	53 + 2	78 + 12	30 + 4	34 + 3
Selenium	.55 + .01	.93 +.52	<.98 + 0	<.96 +.02
Silver	<.05 + 0	<.05 + 0	<.06 + 0	<.06 + 0
Zinc	51 + 0	27 + 12	56 + 23	42 + 7
PAH's total	ND	ND	3.8 + 5.4	ND

Sample Location	CS3	CS3	CS4	CS4
Sample Type	Sed	Soil	Sed	Soil
Fuel Scan				
Petroleum Hydrocarbons	4700	190	19000	30000
Total Solids	52.5+ 1.3	82.3+ 8.1	43.1+ 11.6	61.8+15.6
TOX	14 + 1	8.6+ .8	17 + 4	12 + 3
Metals				
Arsenic	12 + 3	7.9 + 4.4	18 + 6	15 + 4
Barium	125 + 8	84 + 51	195 + 35	120 + 14
Cadmium	1.2 + 0	.20 + .26	12.5 + 7.8	8.8 + 11.7
Chromium	34 + 1	31 + 8	82 + 5	41 + 4
Copper	35 + 8	24 + 20	141 + 69	50 + 10
Lead	42 + 4	6.2 + 4.6	713 + 400	165 + 205
Mercury	.03 + .01	.03 + .01	<.02 + 0	.04 +.01
Nickel	47 + 9	48 + 8	80 + 16	61 + 8
Selenium	<.96 + 0	1.2 + .3	1.6 + .8	1.6 +.8
Silver	<.06 + 0	<.06 + 0	1.4 + 1.0	.26 +.30
Zinc	77 + 4	49 + 32	123 + 187	134 + 65
PAH's total	.41 + .58	ND	15.7 + 4.6	.67 + .11

All units mg/kg except total solids, which are percent.

Table 5. Runway Ditch Soil/Sediment Sample Results (cont.)

Sample Location	CS5	CS5	CS6	CS6
Sample Type	Sed	Soil	Sed	Soil
<u>Fuel Scan</u>				
Petroleum Hydrocarbons	2100	1600	1550 + 71	356 + 416
Total Solids	46.3+ 9.6	39.2+ 3.7	51.6+ 3.3	83.0+ 8.4
TOX	16 + 4	18 + 1	14 + 1	8 + 1
<u>Metals</u>				
Arsenic	28 + 34	38 + 7	22 + 9	23 + 15
Barium	96 + 49	92 + 10	101 + 20	79 + 27
Cadmium	2.2 + .1	2.4 + .1	1.7 + .9	.23 + .20
Chromium	38 + 13	21 + 2	39 + 3	20 + 6
Copper	35 + 18	31 + 6	36 + 2	24 + 11
Lead	45 + 15	55 + 4	45 + 20	15 + 19
Mercury	<.03 + 0	.10 + .01	.03 + .01	<.03 + 0
Nickel	76 + 34	43 + 7	74 + 19	59 + 17
Selenium	.49 + .01	1.05 + .93	.84 + .62	.79 + .28
Silver	<.05 + 0	<.06 + 0	.06 + .02	.05 + .01
Zinc	160 + 71	130 + 28	101 + 24	57 + 17
<u>PAH's</u> total	ND	ND	ND	ND

Sample Location	CS7	CS7	CB1	CB1
Sample Type	Sed	Soil	Sed	Soil
<u>Fuel Scan</u>				
Petroleum Hydrocarbons	5000	1750+ 212	<6.8	56
Total Solids	23.2+ 1.5	21.4+ .8	69.2+ 6.1	79.3+ .6
TOX	31 + 2	33 + 1	10 + 1	<8.8 + 0
<u>Metals</u>				
Arsenic	52 + 12	150 + 28	16 + 6	11 + 1
Barium	68 + 28	149 + 134	102 + 12	82 + 5
Cadmium	4.9 + .3	3.2 + .8	.08 + .09	.04 + .02
Chromium	41 + 4	32 + 1	46 + 8	22 + 2
Copper	120 + 42	92 + 1	38 + 6	14 + 1
Lead	57 + 21	37 + 1	4.5 + .04	7.8 + .64
Mercury	.12 + .03	.08 + .01	.06 + .04	<.03 + 0
Nickel	170 + 42	138 + 11	61 + 18	32 + 9
Selenium	14.5 + 6.4	12 + 5	1.9 + 1.2	<.82 + .07
Silver	1.10 + 0	.51 + .59	<.05 + 0	<.05 + 0
Zinc	385 + 78	305 + 64	69 + 13	54 + 3
<u>PAH's</u> total	.12 + .16	.33 + .25	ND	14.4 + 20.4

All units mg/kg except total solids, which are percent.

Table 5. Runway Ditch Soil/Sediment Sample Results (cont.)

Sample Location	CB2	CB2	SD1
Sample Type	Sed	Soil	Soil
Fuel Scan			
Petroleum Hydrocarbons	97	50	--
Total Solids	70.7+ 3.3	82.2+ 3.0	77.6+ 2.7
TOX	<10 + .4	8.6 + .4	26 + 14
Metals			
Arsenic	5.0 + .4	11 + 2	70 + 27
Barium	82 + 2	97 + 19	90 + 12
Cadmium	<.02 + 0	.03 + .01	.99 + .99
Chromium	22 + 9	50 + 23	48 + 9
Copper	11 + 2	9.1 + .1	44 + 7
Lead	1.6 + .1	7.6 + 3.4	32 + 23
Mercury	<.03 + 0	<.03 + 0	.03 +.03
Nickel	38 + 18	39 + 4	66 + 6
Selenium	<.92 + .01	.94 + .08	.66 + .25
Silver	<.05 + 0	<.05 + 0	.06 + .02
Zinc	38 + 11	57 + 1	95 + 19
PAH's total	ND	.10 + .13	.9 + 1.8

All units mg/kg except total solids, which are percent.
Raw data source: SCS Engineers, 1988.

Since the Dugualla Bay outfall drains approximately 78% of the total air station, pollutants originating from much of the developed and agricultural area of the air station may also be transported through the drainage ditches. Of particular concern is the potential for hazardous and toxic pollutant transport in surface runoff from other Superfund sites within the air station boundaries. These include fuels, oils, solvents, and trace metals from waste storage tank areas, a nose hanger, fuel farms, a fuel truck depot, and smaller sites within the centrally developed core area. The primary concern is that during large storm events or ditch dredging operations the pollutants trapped in the sediments will be released for discharge to Dugualla Bay. These pollutants could result in damage to sensitive wildlife and threatened or endangered species.

3.4 Identifying Specific Pollutants

The understanding of typical highway runoff pollutants, review of the data in Table 5 and the general history of hazardous waste disposal in the watershed results in the conclusion that the contaminants identified in Table 6 could be present in the storm runoff. The most likely sources of the pollutants in Table 6 and rationale for testing for each pollutant will be discussed below. All pollutants should be tested at the first storm with the exception of ethylene glycol. Ethylene glycol content should only be determined if deicing fluids have been used since the last rain event. The sample groups column identifies those tests that are compatible with each other and can, therefore, be performed on one collected bottle. Generally, a single one liter bottle is required for each grab and composite sample per sample group. Mandatory testing for the first eight pollutants is a result of the NURP findings. The remainder are site-specific.

3.4.1 Oil and Grease

Oil and grease, the currently permitted discharge, have many possible sources. These include aircraft and vehicle hydraulic and lubricating fluids and spilled fuel. The density of oil and grease is significantly less than water (both JP-4 and JP-5 have a density of about 0.8, according to the Material Safety Data Sheets) and solubility is low, leading to their tendency to float on water and to create a visible sheen on the water surface. There is a large range of compounds that fit into this category, making volatilization difficult to characterize. Oil and grease tend to sorb well with soil and vegetation. Stenstrom *et al*. (1984) found that the quantity of oil and grease runoff from urban areas is dependent on land use and that the mass discharge is proportional to total rainfall. Most oil and grease in runoff is composed of higher molecular weight compounds.

Only a grab sample is collected for oil and grease analysis. Although an absolute discharge limit has not been established, some research indicates 10 ppb is the lowest observed chronic effect level on marine biota for petroleum-based oil and greases (USEPA, 1986).

Table 6. Pollutant Testing for Permit Application.

Pollutant	Cost ($/sample)	Sample Group	USEPA Table	Grab Only?
Oil and Grease	35	1	2F-2	Y
BOD_5	35	2	___	
COD	25	3	___	
Total Suspended Solids	10	4	___	
Total Kjeldahl Nitrogen	20	4	2F-2	
Nitrate plus Nitrite	17	5	2F-2	
Total Phosphorous	25	5	2F-2	
Fecal Coliform	25	6	2F-2	Y
Surfactants	40	7	2F-2	
pH	5	4	___	Y
Benzene	150	8	2F-3	*
Ethylbenzene	___	8	2F-3	*
Toluene	___	8	2F-3	*
Xylene	___	8	2F-4	*
Arsenic	23	9	2F-3	
Barium	8	9	2F-2	
Cadmium	8	9	2F-3	
Chromium	8	9	2F-3	
Copper	8	9	2F-3	
Lead	8	9	2F-3	
Nickel	8	9	2F-3	
Zinc	8	9	2F-3	
Phenols, total	40	10	2F-3	Y
PAH's, specific	190	11	2F-3	
Total Organic Halogens	120	12	2F-3	*
Ethylene Glycol	175	5	none	

* Grab samples are collected and composited in the laboratory to minimize loss of volatile compounds.
Cost data furnished by Lauck's Laboratory, Seattle.

3.4.2 BOD_5

The five day Biochemical Oxygen Demand test measures the microbial demand for oxygen and indirectly indicates the presence of degradable organic matter. High BOD_5 values could indicate the presence of human or animal waste, decaying plant material such as leaves, grasses, or clippings (Lager, *et al.*, 1977). Permit limits for storm water BOD_5 discharge have not been set. The most likely potential source at the air station is the field used for cattle grazing. Leachate migration from failed septic tanks in the surrounding community is also a potential, though less probable, pollutant source.

3.4.3 Chemical Oxygen Demand (COD)

Not all chemical compounds are degraded by bacteria. This test evaluates the potential for chemical oxidation of the waste stream, and sources are often the same as those for the biological test (Lager, *et al.*, 1977). A large discrepancy between the COD test result and the BOD_5 test result would indicate the presence of an industrial pollutant source. COD discharge limits have not been set.

3.4.4 Total Suspended Solids

Depending on the receiving water characteristics, total suspended solids (TSS) may be a direct pollutant to the ecosystem. In the Dugualla Bay area, and considering the relatively quiescent drainage ditch flow conditions, total suspended solids do not appear to be a problem for the air station. However, research suggests that the quantity of suspended solids in storm water runoff can be correlated to both organic and inorganic pollutant load in the discharge (Wu and Gschwend, 1986; Zison, 1980; Donigian and Crawford, 1977). Eganhouse, *et al.* (1981) found that 85% of hydrocarbons in storm runoff were associated with suspended solids. Therefore, sampling to determine the suspended solid concentration may be useful as a low-cost indicator of other pollutants. In addition, chemically precipitated pollutants in the sediments may be resuspended if the sediments are disturbed, as they could be during high flows and likely will be when Superfund cleanup of the ditches begins. Because of the pending site remediation, background TSS information is especially important.

The major sources of non-background suspended solids are runoff from construction or agricultural activities. The dirt and debris released from cars and trucks during a storm event have also been shown to be significant sources of suspended solids in urban runoff (Asplund, 1980). If performed at least every two days, street sweeping may be effective in reducing TSS loads in urban runoff (McCuen, 1978). Military airfields are cleaned every day by street sweeping equipment, so TSS loadings from the runways and taxiways should be very low. However, runoff from the roads and urbanized areas of Ault Field that is carried by the drainage ditches could have a high solids content. Moreover, seasonally high solid loadings can occur when air station roads are sanded during icy weather. While much of the road sanding results in settleable solids, it has also been shown to increase dissolved constituents (Chui, *et al.*, 1982).

The Skagit River, which empties into Skagit Bay, is the largest contributor of suspended solids to Puget Sound (PSWQA, 1988). This may be significant to the permitting process for Ault Field, since Dugualla Bay is an embayment of the larger Skagit Bay. Suspended solids are sometimes measured as turbidity units (NTU). Water quality criteria in Washington limit NTU of discharges to 10% of background in excellent waterways and 20% of background in good or fair receiving waters (USEPA, 1988). While not strictly accurate, dividing low TSS values by 2.4 will yield an approximation of the corresponding NTU (Tchobanoglous and Burton, 1991).

3.4.5 Total Kjeldahl Nitrogen

Total nitrogen is a measure of ammonia and organic nitrogen. Nitrogen is a basic nutrient of bacteria and algae and excess nitrogen can lead to eutrophication of receiving waters. Human or animal waste, decaying grass or plants material, and fertilizers from landscaped or farm operations contribute to nitrogen loadings (Lager, *et al.*, 1977). The cattle grazing performed on the leased agricultural land could be a major contributor to ammonia nitrogen loads. In freshwater, ammonia limits are a non-linear function of pH, temperature and fish species present. In neutral pH salt water, adverse effects have been observed at concentrations as low as 280 ppb (USEPA, 1988).

3.4.6 Nitrate-plus-Nitrite Nitrogen

By-products of the bacterially mediated oxidation of ammonia-nitrogen, these compounds can be toxic to humans or other mammals if present at excessive levels. Sources include human and animal waste, leaching from septic systems and fertilizer in runoff (Lager, *et al.*, 1977). While all buildings on Ault Field are connected to a central sewage treatment plant, private residences within the ground water basin that drains into the Ault Field ditches do use septic systems. Since nitrates are not easily sorbed to soil particles (White, 1979), it is possible that nitrates are released into the storm ditches from the groundwater. There are no Washington state regulations limiting nitrate releases, so the 10 mg/L drinking water regulation may be applied to storm releases (USEPA, 1988). In addition, more stringent standards may be set if algal blooms become a problem in the stilling basin or Dugualla Bay.

3.4.7 Total Phosphorous

Phosphorous is also an essential nutrient for most algae and microbes, and in freshwater environments it is usually the nutrient that limits growth (Welch, 1980). It is essential to marine life as well, although the elemental form of phosphorous is toxic to plants at 10 ppb (USEPA, 1988). Sources include fertilizer runoff, detergents and decaying vegetation and animal waste. The impact of soluble phosphorous on Dugualla Bay could not be determined, but nitrogen is more likely to be limiting nutrient in marine environments (Welch , 1980). While elemental phosphorous would not be in the storm discharge at the air station, other forms of phosphorous likely to be present could cause receiving water problems.

3.4.8 Fecal Coliform

Fecal coliform bacteria counts are used to indicate the possible presence of disease-causing bacteria. In drinking water sampling, a fecal count above the standard may require a more detailed and through sample to identify the specific bacteria present. This detail is not necessary for storm water sampling. Elevated fecal counts indicate the presence of waste products of human or other animals. This could indicate the presence of sanitary sewer cross connections or failed on-site disposal systems. It could also result from the defecation by cattle, wildlife or household pets within the watershed (Lager, *et al.*, 1977). A good indicator of the presence of fecal bacteria would be the posting of Dugualla Bay as off limits to shell fishing, an action which has not been necessary. The USEPA recommends average bacterial counts of less than 14/100 mL sample for shellfish areas, although the Washington State standards are lower in already degraded receiving waters (USEPA, 1988).

3.4.9 Surfactants

Surfactants are used in detergents to remove dirt and grime. The MBAS foaming agents test determines their presence. Potential sources include the private washing of cars and improperly connected aircraft wash facilities. Surfactants have been shown to release polycyclic aromatic hydrocarbons (PAH's) that have sorbed to soils (Liu, *et al.*, 1991), so their presence could result in the storm discharge of other pollutants. No discharge standards have been established for surfactants.

3.4.10 pH

The pH test provides a relative measure of the acidity or alkalinity of the runoff. The simple field test is important since nearly every ionic compound can affect it and since most chemical and biological reactions occur within very specific pH ranges. The pH gives useful information on the affinity of a pollutant to adsorb to soil particles, the productivity of bacteria, and the potential for precipitation. It is also useful for predicting which ionic species of a chemical may be present in the waste water. Toxicity characteristics of many compounds, especially metals, can be altered by changes in the pH of a water. Recommendations for salt water discharges are in the range of 6.5 to 8.5, and 6.5 to 9.0 for fresh water discharge (USEPA, 1988).

3.4.11 Benzene, Toluene, Xylene and Ethylbenzene

These common monocyclic aromatic petroleum constituents are sampled as part of the BTX&E mass spectrometer test. Benzene in water primarily volatilizes to the atmosphere with reported half-life values in a mixed one meter water column of five hours. Benzene also has a relatively high solubility, which may result in its presence in the runoff. It is biodegraded at low concentrations by ubiquitous organisms. Adsorption to suspended organic sediments is high. Ethylbenzene is relatively less volatile, although volatilization is still the primary removal mechanism. It has a higher octanol-water partition coefficient than benzene, an indication of an increased tendency to adsorb to sediments. Toluene and xylene volatility, solubility, and partitioning coefficients fall in between the upper and lower limits of ethylbenzene and benzene (Callahan, *et al.*, 1979).

They are major components of automotive and aviation fuels, and therefore have a high probability of being present in any storm runoff from Ault Field. Aromatic hydrocarbons are also present in one wash rack solvent, although the exact concentration was not determined. The chemical composition of JP-4 and JP-5 depends on the source of crude oil and the refinery which produces the fuel. The higher volatility and vapor pressure of JP-4 is indicative of a higher Benzene concentration than in JP-5. JP-5 is very similar to number 2 diesel fuel (Clewell, 1984). Discharge limits have not been set, but the lowest observed chronic toxicity effect levels for benzene and toluene have been 700 and 5,000 ppb, respectively, in marine water environments.

Ethylbenzene acute toxicity has been reported as low as 430 ppb in marine environments (USEPA, 1986).

3.4.12 Metals

Transport and fate of metals is generally controlled by sediment sorption or chemical complexation and precipitation. Most metal ions are positively charged and increasing the pH increases their precipitation. They are generally non-volatile. Based on the sediment sampling of the drainage ditches, the following metals may be present in the effluent in concentrations greater than 10 ppb: arsenic, barium, cadmium, chromium, copper, lead, nickel, and zinc. Washington State has adopted USEPA toxicity guidelines as legal discharge limits (WAC 173-201-047).

Arsenic is commonly found in lubricants and petroleum products, as well as pesticides and herbicides. It is extremely mobile and may precipitate with other metals (Callahan, *et al.*, 1979). The high concentrations found at location CS7 may be the result of past pesticide use. Chronic and acute toxicity in marine waters is reported as 190 and 360 ppb, respectively; and fresh water toxicity limits are about five times higher (USEPA, 1986).

Barium is added to diesel and aviation fuel as a smoke depressant, is contained in grease, lubricating oils and vulcanized rubber and may also be present as the result of prior paint or Hanger 6 disposal practices (Patterson, 1985). Compounds of barium are readily soluble, but very few natural waters contain concentrations in excess of 100 ppb. Sorption on sediments and precipitation are the principal removal mechanisms (Hawley, 1981). Toxicity in the environment is unknown, although the drinking water standard is 1,000 ppb (USEPA, 1988).

Cadmium is also relatively mobile and may complex with organics or adsorb to sediments (Callahan, *et al.*, 1979). Cadmium is found in zinc-containing products, and contamination may be the result of caustic rinsate discharges. Chromium from prior rinsate discharges is very soluble and toxic in the hexavalent form at fresh water concentrations as low as 11 ppb. Marine chronic toxicity is reported at 50 ppb (USEPA, 1988). A complex anion, it is not sorbed to clay or metal oxide sediments, but it is strongly adsorbed by activated carbon (Callahan, *et al.*, 1979).

Copper may have been in the waste paints or strippers dumped from the ground equipment shop. It is usually removed from water by sorption to soil particles but can also be removed by complexation with organics and other heavy metals or by biological activity (Callahan, *et al.*, 1979).

An essential nutrient, it is also toxic at the low salt water concentration of 2.9 ppb. Fresh water chronic toxicity is a function of water hardness but is reported as 12 ppb or higher (USEPA, 1988).

Lead is strongly sorbed to soil and will most likely only be transported when sediments are disturbed (Callahan, *et al.*, 1979). Its source in the drainage ditches is most likely the result of paint and rinsate disposal. It may, however, be the result of sediment runoff from the roadways or fuel farm site. The presence of lead in highway runoff is well documented (McCuen,1978; Asplund, 1980; Lager *et al.*, 1977). With no known nutrient value, its salt water chronic toxicity threshold is 5.6 ppb, although the acute toxicity is a much higher 140 ppb. Fresh water chronic and acute toxicity of as little as 3.2 and 82 ppb, respectively, is dependent on hardness (USEPA, 1988).

Nickel is much more mobile than other metals and sorption processes occur most readily when organics are present. Under neutral aerobic conditions, such as found in the drainage ditches, nickel forms compounds with common water ligands and remains soluble (Callahan, *et al.*, 1979). Sources at Ault Field include paints and rinsates, as well as runoff from other contaminated areas. Nickel is more toxic in salt water than fresh water environments, with a chronic limit of 7.1 ppb and an acute limit of 140 ppb. Fresh water chronic and acute toxicity limits are hardness dependent, but toxic effects have been observed at concentrations as low as 160 and 1,400 ppb, respectively (USEPA, 1988).

Zinc tends to adsorb onto iron and manganese oxides, clay minerals, and organic matter. The composition of dissolved and suspended solids can alter the mode of transport: zinc will adsorb to suspended solids, but remains in solution if only dissolved solids are present (Callahan, *et al.*, 1979). Zinc contamination appears to be the result of caustic rinsate dumping. Hardness dependent, fresh water toxic effects have been observed at concentrations as low as 110 ppb, and acute effects are observed at 120 ppb. Salt water chronic and acute limits are 58 and 170 ppb, respectively (USEPA, 1988).

Background sampling of native soils for metal content may be advisable, since several of the above priority pollutant metals can occur naturally in soils at concentrations higher than 10 ppb. Yousef and Lin (1990) found that the extractable metal concentrations of sediments decreases as clay and organic content increases. Of course, a high soils concentration does not necessarily translate to a high storm water concentration of a given metal, since suspension of the soil particle and attached metal would be diluted in a large quantity of water. However, the minimal cost of metals testing, less than $10 per metal, makes this analysis worthwhile.

3.4.13 Total phenols

Total phenols analysis will include 11 separate priority pollutants. In general, phenols are not likely to volatilize to the atmosphere or adsorb to soils or sediments. They tend to complex metals and are easily biodegraded and photodegraded (Callahan, *et al.*, 1979). Despite this tendency to degrade, they may be present in the runoff due to past disposal of caustic rinsates from Hanger 6 or as the result of the natural degradation of organic waste. Salt water acute toxicity is reported as 5,800 ppb, and fresh water limits are 2,560 ppb chronic, 10,200 ppb acute (USEPA, 1986). The recommended test is non-specific and will not identify a particular phenol compound. However, the low probability of encountering phenols in the discharge does not seem to justify performing a more expensive analysis.

3.4.14 Polyaromatic Hydrocarbons (PAH's)

PAH's are a complex and numerous group of petroleum constituents and combustion by-products. A typical concentration in fuels is 30 to 100 mg/kg (McCabe, 1988) and the concentrations found in the drainage ditch soils are consistent with this range, based on the raw fuel concentrations identified in Table 5 soil/sediment data. Despite this apparent correlation, a specific analysis is proposed because PAH's may be present in burnt jet fuel. In fact, Table 5 seems to indicate a relatively higher soil concentration at site CS7, near the end of the main runway, than at the baffles. PAH's were usually present in the Ault Field soil/sediment samples in the form of naphthalene, acenaphthylene, acenaphthene and flourene, although phenanthrene and pyrene were also detected. Naphthalene is the most soluble in water and the PAH's decrease in solubility in the order listed. Once dissolved, they undergo photodegradation (Callahan, *et al.*, 1979). PAH's tend to adsorb strongly to suspended particles, which may account for their increased concentrations at points of low flow in the drainage ditches. There is no established discharge limit for PAH's, but the lowest observed effect in a marine water occurred at a concentration of 300 ppb. Acenaphthene toxicity has been reported at 520 ppb, and fresh water chronic naphthalene toxicity as 620 ppb (USEPA, 1986).

3.4.15 Halogenated Organics

The presence of tetrachloroethene, trichloroethene (TCE), isomers of dichloroethene, vinyl chloride, carbon tetrachloride and its degradation by-products, and tetrachloroethane and its by-products in the runoff is possible due to the past practice of dumping solvents. Soil analysis indicated the presence of small amounts of halogenated organics. More significantly, groundwater samples in the Ault Field central area reveal halogenated organic concentrations as high as 370 ppb (SCS Engineers, 1988). The emergence of this groundwater in the storm ditches could result in storm runoff concentrations greater than the 10 ppb threshold, and therefore a specific total halogenated organics (TOX) scan for these solvents and their by-products should be conducted. Even if present in groundwater discharge, these solvents tend to volatilize from surface waters quickly (the reported half life is less than one hour for most) and are not very likely to adsorb to suspended material (Callahan, *et al.*, 1979). Toxicity thresholds vary widely by compound (USEPA, 1986).

3.4.16 Ethylene Glycol and Wash Rack Solvents

Ethylene glycol, used for deicing aircraft, is extremely soluble in water (Weast, 1989) but its environmental fate is uncertain and acute toxicity levels could not be located. It is not one of the 225 pollutants that requires testing to meet the permit requirements. Because of its limited usage, total annual loadings are expected to be minimal. Using the reported 0.35 million gallon daily average pumped effluent flow for December of 1990, and multiplying by four to account for flow through the tide gate, use of just one 55-gallon drum per day could result in a discharge of 40 ppb. While this estimate assumes that no degradation occurs and there is uniform mixing throughout the daily flow, it does demonstrate that the 10 ppb threshold could be exceeded, and the daily loading could be relatively high. Including a storm water test for ethylene glycol may be prudent if the deicer was used since the last rain event.

The fate and transport of dipropylene glycol methyl ether, alkylaryl ethoxylate and capric acid diethanolamide used for general purpose aircraft cleaning is also uncertain. Small quantities of these compounds are used on a regular basis, and concentrations in the discharge are not likely to be greater than 10 ppb under most flow conditions.

3.4.17 Other Possible Pollutants

Pesticide and herbicide screenings were performed on soil and water samples collected in other parts of Ault

Field, and no priority pollutant contamination was found in either medium. There exists some potential for runoff from the agricultural lease areas, although the use of herbicides and pesticides in these areas is crop-dependent, sporadic, and seasonal. According to one of the lease holders, they are not applied during known rainy periods (McMoran, 1991). They would most likely appear in runoff sorbed to sediments from the agricultural areas. The low application rate and quick volatilization, transformation and photodegradation of these compounds (Callahan, *et al*., 1979) makes effluent testing unnecessary for most storms. However, if an application is made within 7 days of a qualifying rainstorm, the runoff should be sampled for traces of the recently applied substance. None of the priority pollutant pesticides are in use. As already noted, the high concentrations of arsenic found at location CS7 may be the result of past pesticide use.

3.5 Statistical Power of Monitoring Program

There are two sampling programs that must be undertaken as part of this permit process. The first is the background sampling necessary to determine the pollutants for which the USEPA will require routine testing when the NPDES permit is renewed. The second is the continued monitoring to determine compliance with the limits set in the permit.

Background sampling, per the new regulations, is a one-time sample of all contaminants which might be present in concentrations greater than 10 ppb. Background sampling must rely on historical standard deviations for a given test method to determine the statistical reliability of the data. The USEPA accepts data submitted by their certified laboratories as within acceptable limits. Accordingly, the Navy must collect and test one grab sample and one flow-weighted composite sample for each pollutant which may be present. If one contaminant is discovered at what appears to be an unusually high level, then confirmation samples could be collected for that pollutant.

The difficulty with doing a more thorough sampling program at the background level is that the USEPA has not defined what would be a significant release of any of the contaminants. Therefore, the real goals of the sampling are difficult to establish and a method to maximize the effectiveness of the sampling regime cannot be determined. The current permit allows 10 mg/L average per month and 15 mg/L daily maximum of oil and grease in the discharge, typical industrial discharge limits. The limits for sewage treatment facilities are based on the level of treatment considered technically feasible. No such standards have been set for nonpoint discharges.

Once the objective of monitoring has been identified by the USEPA, the sampling program can be established with the intent of documenting compliance in the most cost-effective and statistically valid method. Nonetheless, some assumptions can be made about the monitoring program to demonstrate the adequacy of sampling during storm events only, instead of uniform sampling in space and time.

The PC-based DESIGN program was used to determine the power of various test frequencies for oil and grease sampling only. Assumptions and results of each run are provided in Table 7. The cost estimates are very rough, since the current monitoring program costs could not be determined. The available budget was selected to approximate the actual expenditures over a five year period. Overhead of $2,600 is for the review and reporting of sample results and the procurement of a tipping scale rain gauge and recording flow meter. Field time is estimated at $50 an hour, and one hour would be adequate for collecting the sample from an automatic sampler. If the sample had to be manually collected, two hours minimum per event ($100) would be needed. Costs include the equipment used in the field and delivery to the lab. If the analysis required a composite sample, then a cost per event of $250 for manual collection or $50 for automatic collection would be appropriate. The $5,900 cost per station is for an ISCO automatic sampler with batteries and three solar recharge cells. Cost estimates for the replicate laboratory work are from Table 6. The selection of one season means that the program assumes the testing is evenly spaced. Although this is not strictly true, it is consistent with the assumption that loadings occur evenly with each storm. Variance based on reported peak values of Table 1 is 0.7, and this was assumed to be the natural variance. The years of sampling, number of stations and number of replicates per event were estimated as maximums.

Measurement error variance of 0.5 is estimated based on literature values (Mar, *et al.*, 1986) and was considered reasonable for oil and grease by Lauck's Laboratory. Type I error level of 0.05 equates to a 95% confidence level. Although the actual Delta of interest is about 10 times the currently reported values, runs made with Delta equal to 10 produced a power of 0.391 at one sample event (with a near doubling of the power if an additional sample station were added), 0.847 at two sample events, and a very high power of 0.978 at only four events. In order to provide a meaningful demonstration of the declining benefits in statistical reliability as the number of samples increased from 1 to 52, Delta was set at 2. A similar effect could have been obtained by increasing the natural variability. The largest variable, the number of events sampled, was adjusted from 1 (for permit approval) to 30 (estimate of number of qualifying storms) to 52 (current sampling frequency). Assuming the automatic sampler was inoperative half the time, the power of 15 samples is also reported. To determine the actual power of each trial, the minimum power was set to zero and the program was run to minimize cost.

Table 7. Sampling Program Statistical Effectiveness.

Input Assumptions	Run 1	Run 2	Run 3	Run 4
Available budget ($)	90000	90000	90000	90000
Overhead cost ($)	2600	2600	2600	2600
Cost/Sample event ($/event)	50	50	50	50
Cost/Station ($/unit)	5900	5900	5900	5900
Cost/Replicate ($/unit)	35	35	35	35
Control stations (Y/N)	N	N	N	N
Number of seasons/year	1	1	1	1
Number of events/season	1	30	52	15
Years of sampling before and after intervention	1	1	1	1
Maximum number of stations	2	2	2	2
Maximum number of replicates	2	2	2	2
Variance due to natural variability over time	.7	.7	.7	.7
Measurement error variance	.5	.5	.5	.5
Delta (the step change)	2	2	2	2
Level of Type I error	.05	.05	.05	.05
Statistical power desired	0	0	0	0
RESULTS				
Power	.131	.880	.951	.744
Added Power/Replicate	.010	.034	.018	.048
$/.01 Power increase for replicates	147	1250	3937	438
Added Power/Station	.106	.083	.049	.136

Results for the oil and grease example list the power for the given variables, the added power if additional replicates were taken at each event, the cost per unit of power added by the additional replicates, and the added power if an additional sampling station is added. Note the rapid improvement in power, from 0.131 to 0.744, obtained by increasing the number of samples from 1 to 15 per year. The added improvement by sampling 30 events is much less significant. While the cost data are very rough, the analysis does demonstrate that each additional step of improvement in the statistical reliability of the data costs more than the previous step. At some point in a monitoring program, the added benefits of additional sampling outweigh the costs.

The program also computes the cost per added station and per year of sampling as part of the sensitivity analysis. but these unit costs were always substantially higher than cost per added replicate for the automatic sampler. Adding an additional sampling station always increased the power the most, but the unit cost was high unless manual sampling was performed.

3.6 Sample Location

Testing at multiple locations will provide no benefit to the program, since the concern is the point discharge value. If the USEPA insists on testing at the point of discharge to Dugualla Bay (i.e. the pump station), then it may be desirable to perform background sampling at the point where the runoff leaves Navy property. This may identify if a problem is coming from Navy or non-Navy land. Sampling of the storm runoff from the developed central area of the base before it enters the storm sewers under the flight line may also be desired if the TSS loading in the discharge is high. If the TSS load is primarily a result of central area runoff, then sediment removal facilities should be located prior to storm water crossing under the flight line.

3.7 Permanent or Temporary Test Station

Permit testing requires the collection of grab and flow weighted composite samples. At the time of sampling, a flow estimate must be made. At least 100 mL of liquid must be collected at regular flow intervals to create the composite samples required to characterize the pollutant loading. An equal size sample can be collected each time a set amount of water has passed the sampling location, or a set time can be allowed to pass and the sample size can be increased or decreased based on the flow. In either case, two things are necessary: a reliable method for determining the flow and a reliable method for collecting the sample.

Determination of a flow discharge equation can usually be made based on the Manning coefficients for channel roughness, the channel dimensions and the channel slope. In the case of Ault Field, the backwater elevation from the stilling basin must be factored into the equation. A more accurate flow measurement can be made if a flume or weir is installed across the channel. The quantity of flow can then be computed based on the elevation of the water over the weir or in the flume. The elevation can be determined by an ultrasonic sensor above the water, a pressure transducer within the water or a bubble injector which can determine the amount of pressure necessary to inject a given amount of air. The continuous flow readings can then be plotted on a paper cylinder or relayed via modem to a central monitoring location. There are several manufacturers of commercial automatic flow monitors and recorders. Calculations could be made based on the determined discharge equation and the elevation of the water in the channel. If water elevation is recorded at a regular time interval, a reasonable approximation of the total flow volume could be made.

Sample collection can be done with a refrigerated automatic sampler that is connected to a flow meter, a permanent compositing meter such as the one developed by Clark (1980), or by an individual with a bucket. Clark developed a sampler that was placed midchannel and split the flow until the desired sampling percentage was obtained. This sample quantity was sent to a concrete box with plastic lining. While it required no power, minimal maintenance, and did not require a timely response at the start of a storm, it had some drawbacks. Its usefulness on large watersheds or in a continuously flowing channel would be impractical. It also needed to be placed on a sufficient slope to maintain supercritical flow. While it would not work for the drainage ditches, an inexpensive continuous composite sampler would be useful for identifying a contaminant in runoff from a specific source, such as the fuel farm.

The most challenging aspects of storm water sampling are the requirement to sample within 30 minutes of the beginning of a storm and the need to sample continuously throughout the storm. This rapid response requirement may favor the use of a permanent automatic sampler that can receive a signal to start collecting from a recording rain gauge and can automatically composite samples based on flow over a weir.

Manual flow recording and sample collection is adequate for initial sampling. If a laboratory will not be collecting the samples, then the certified laboratory could be used to train a station individual in collection and transportation procedures. However, a permanent sampling location will reduce the errors associated with manual collection and help ensure the repeatability of sample results.

Determining the features of a permanent monitoring and sampling system depends on the pollutants that must be monitored. Different testing parameters require different minimum sample sizes. Some samples, such as metals, require preservatives to be added to the collection bottles.

3.8 Background Test Requirements

Background testing of storm water will become important if a treatment technology is needed to remove the spilled aviation fuel or some other pollutant or if an off-base land use is suspected of being a contaminant source. This is because testing storm water before it enters the storm sewers and flows under the apron may reveal high pollutants from a source other than the runways. Pollutants may be transported from sources such as the roadways, housing area, developed industrial area, construction zones or other Superfund cleanup sites. Urban storm water pollutants can also be transported via surface or groundwater from off station sources, and have been shown to originate in precipitation (Little, *et al.*, 1983), although precipitation of pollutants at Ault Field is unlikely. If an unexpected pollutant is discovered during sampling, additional samples should then be collected closer to the suspected source. It may then be possible, and more economically efficient, to reduce or treat only the source of the most significant contamination.

4.0 DISCUSSION

4.1 Sampling Frequency

The data collected in the past have a low probability of identifying a pollutant release, since they were not keyed to spill or storm events. In fact, they do not even represent a random sample, since the day of collection, Sunday, may represent a period of least likely occurrence. For example, fuel spills and storm water flow time could be such that spills during peak weekday flight line operations have already passed the sampling point prior to the time chosen for sampling. Efforts are underway to prevent spills and clean all small spills with dry sorbents instead of hosing the fuel into the drainage system. If these efforts succeed, the current testing program will have even less chance of discovering a true release. Nonetheless, the prior record can be considered a reliable indicator of background effluent concentrations.

It would seem possible to relax the current weekly testing during the dry summer months, since the possibility of a release during low flow is substantially less. The new regulations requiring testing during and following storm events recognize this and should result in being more capable of determining a true receiving water loading rate. Many studies document the variation of storm water pollutant loading (Clark, *et al.*, 1981; Chui, *et al.*, 1982; Asplund *et al.*, 1982; McCuen, 1978), and the sampling program should seek to record the variation at this site. The storm pollutant loading is not predictable in the same manner as a domestic wastewater treatment plant loading, and the permit will not treat them the same. Storm event frequency data were given in Table 2. An average of 30 events per year were recorded between 1984 and 1989. If sampling was keyed to storm events, up to 22 fewer samples per year would have required collection and analysis. Because there is no way of knowing within 30 minutes of the start of a storm if 0.1 inches of rain will fall, some samples will invariably be collected which do not require testing. These erroneously collected samples were accounted for numerically in the statistical program but the costs were not included. An alternative would be to test after a spill at a time interval calculated to coincide with the arrival of the spill at the sampling point. This would be less reliable than storm sampling, however, because the flow time would change depending on the amount of water used to flush the spill, the existing channel flow rate, and, for Ault Field, the stilling basin level and groundwater infiltration rate.

As might be expected, the computed statistical powers demonstrate that very little improvement in statistical reliability is gained from expanding testing from 30 events to 52 weeks, especially if a Delta of 10 is used. While these data were prepared for oil and grease, similar Delta values, natural variances and measurement errors can be assumed for other pollutants, and the computed power would not change. The cost per unit improvement would be altered, since composite costs are different than grab samples and replicate costs are also different.

Although the requirement for the single sample needed for permit reissue does not represent a statistically valid sample, the use of the last several years of data will make it meaningful for oil and grease discharges. For other pollutants, the large step change (Delta = 10) that would be anticipated for approved discharge makes the single sample useful, even if flawed. In addition, sampling at an additional station would nearly double the power, to 0.765, for only the cost of collecting the grab and composite samples and having them analyzed.

More significant is the question of whether sampling peak storm event discharges will reveal useful data about the environmental impact of a pollutant release. Biological monitoring, though more expensive and time consuming, would reveal the overall ecological health of the receiving water. Bioassessment of the receiving water may indicate that the continuing low concentration oil and grease loads are more detrimental to the environment than the shock loads that occur during storm events.

4.2 Sample Location

The permit should be modified to correctly identify the test location. Ironically, the current sample location could yield a higher suspended solids concentration than the sampling location in the permit, because the runoff has not been through a defined stilling basin, or diluted by two springs which also discharge to the basin. Since most contaminants are bound to the suspended solids, a high TSS concentration will most likely result in a higher pollutant loading.

There are four potential sampling locations identified on Figure 1:

1. The pumped discharge area, channel station 0 + 00.

2. The Navy property line, station 52 + 00.

3. The point of discharge from the dredged channel to the point of natural meander, station 83 + 00.

4. At the third baffle, station 104 + 00.

Each of the above locations has some defensible rationale for its selection. The pumped discharge is the actual controlled point discharge to the receiving waters. A facility property line is the traditional regulatory control location. The natural meander is really the natural receiving water for the drainage from the low lying areas of Ault Field that were filled for runway construction. The third baffle is the first location at which all runoff from the runways, taxiways, and airport facilities comes together. Since any could be selected, other criteria must be considered.

Access to sites 1 and 4 is best, since sites 2 and 3 are in the agricultural fields and roads are limited. Sites 2 and 3 also are at or below sea level, and experience seasonal flooding during periods of high tides and heavy rainfall. Availability of electrical utilities at sites 2 and 3 is also limited, although solar cells and battery packs could be used for sampling equipment.

The selection between sites 1 and 4 in large part must reflect a decision on what will be monitored. Site 1 will include pollutants from non-Navy land and Navy-owned agricultural areas, a problem it shares with sites 2 and 3. Site 4 will exclude most agricultural and off-base originating runoff, but industrial pollutants such as metals and oil and grease will be at a maximum. Because the permit is based on the industrial designation of Ault Field, sampling at location 4, the third baffle, seems to be the most appropriate.

Revising the sample location may result in the storm water being classified as a "fresh water" discharge instead of a marine discharge. Because most contaminants are more toxic in fresh than salt water, this could result in a more stringent discharge standard. Such a determination could, of course, significantly change the cost of compliance with the permit requirements.

4.3 Contaminant Testing

Recommended pollutant testing for permit renewal is provided in Table 6. Contaminant selection was based on the regulatory requirements of the final rule after considering historical waste handling practices, the environmental fate of the pollutants and toxicity discharge limits. The USEPA will identify the requirements for contaminant testing based on results of the initial testing. It may be possible to maximize the usefulness of the compliance testing by testing regularly only for certain indicator pollutants. Depending on which pollutants are revealed as significant during the initial sampling, specific indicator pollutants which can be identified inexpensively may be substituted. More detailed sampling would only be necessary if the indicator is outside an acceptable limit. There is much research effort being directed towards linking total suspended solids with specific pollutant loading through the use of ratios (see section 3.4.4). If successful, sampling program cost savings could be realized. Linking contaminants with specific biological damage in the receiving water could also result in cost savings for routine monitoring. If adverse effects can be demonstrated from a specific pollutant, then water monitoring may be performed only to detect the presence of the pollutant which causes the environmental harm.

4.4 Flow Estimation

A flow estimate needs to be made at the time of sampling. Therefore, the existing channel needs to be calibrated for a depth versus discharge equation. If only oil and grease need to be monitored on the renewed permit, then a calculated discharge equation and mounted flow depth gauge would be adequate, since only grab sample results and the flow at the time of sampling must be reported. If composite samples must be collected as part of the permit compliance, then a permanent flume or weir should be installed to simplify and improve the accuracy of the flow measurement and reduce the flow weighted composite sampling errors. Sampling at the third baffle will improve the flow estimation, since the tidal effects on the stilling basin level are less significant.

An enhanced monitoring program will provide valuable background data for monitoring the Superfund cleanup process or routine channel clearing. Since many of the contaminants are not expected to be released unless the soil is disturbed, knowing background levels in the discharge will be important to evaluating effectiveness of cleanup process controls. The usefulness of the database improves significantly as testing continues for additional years (Mar, *et al.*, 1987). Perhaps by the time site cleanup begins, enough data will have been collected to monitor the cleanup sediment controls effectively.

Use of manually collected data should be pursued for the initial sampling, because there is insufficient time to install permanent equipment. Sajan Engineering should be able to determine a discharge relationship for the existing channel once they have concluded their analysis of the stilling basin level effect on the storm discharge. A determination of the residence time in the stilling basin and the drainage ditches would also be useful, since many contaminants may degrade before they can be transported to the discharge point.

4.5 Mitigation of Storm Water Pollutants

The mitigation of storm water pollutants, by either cleanup or prevention, is very site- and pollutant-specific. The nature of a site's geology, geography, environmental sensitivity, receiving water characteristics, regulatory environment and public perception must all be considered. Technologies that work well for one pollutant may not work for a different pollutant and a combination of two or more treatment methods may be necessary (Amy, *et al.*, 1987; Martin, 1988; McKinnon and Dyksen, 1984; Kerr, 1990).

To fully evaluate the management practices or structural improvements that would work best at NAS Whidbey Island, the pollutants that require mitigation must be known. Since these will not be available until after outfall testing and issuance of the renewed permit, some assumptions must be made before suggesting treatment strategies.

It is likely that oil and grease testing will be required by the new permit since it is presently regulated. This paper also assumes that total suspended solid (TSS) monitoring will be required under the new permit because of the potential for relating the TSS concentrations to specific pollutant concentrations. Fecal coliform may be of interest due to the presence of shellfish beds in Dugualla Bay. Revising management of the agricultural outlease acreage could stop the major bacterial source of contamination if a problem is demonstrated. Review of the water quality criteria for the suspected contaminants identifies no other high risk contaminant that would not be bound to suspended solids. Accordingly, the cleanup technologies for oil and grease and TSS will be reviewed. The compatibility of these technologies with volatile organic or heavy metal contamination cleanup will be considered, since applicable priority pollutant monitoring may be necessary once CERCLA site remediation of the drainage ditches begins. The qualitative evaluation of structural improvements capable of mitigating oil and grease and TSS loads relies heavily on proven technology at similar facilities.

While the baffles clearly remove some floating product, there are also some significant deficiencies. During very high flows, storm water discharging over the top of the baffles can release any previously trapped oil or grease. Visible staining of the soil and vegetation at the baffles indicates that much of the pollution is adsorbing onto the soil. There are several hundred feet of unlined open channel flow before the first baffle which may be contaminated by sorption of fuel products. As demonstrated in Table 3, recovered product is only a small fraction of the quantity spilled and weather conditions can make product recovery difficult. Finally, the existing system continues to contaminate a National Priority List site.

4.6 Best Management Practices

The use of Best Management Practices (BMPs) should be the first line of defense against any contamination. BMPs are generally considered "soft" improvements but they can be extended to include the design of structural or "hard" improvements. Utilizing BMPs as part of proper prior planning has been shown to reduce the environmental compliance implementation cost by as much 500% (Finnemore, 1982b).

Identifying the "best" BMPs for a given location is very site- and contaminant-specific. Nonetheless, some general BMPs have been identified as effective for managing specific runoff pollutants at many different sites.

The mechanical sweeping of streets can be effective at reducing the total solids and heavy metals content of highway runoff, although reduction of organic and nutrient loadings is limited (Finnemore, 1982b). McCuen (1978) reported good removals if streets were swept every two days, and limited effectiveness if swept at weekly intervals. Reducing the peak flow velocity and quantity by requiring on-site detention or infiltration of storm water is proving effective for a wide range of contaminants in Bellevue, Washington. Reducing peak flows also prevents erosion of channel beds, which may re-suspend pollutants. Construction activities, which the U. S. Soil Conservation Service has noted contribute significantly to the sediment loading of the storm system at NAS Whidbey Island, can be required to plant cut or fill slopes as soon as final grades are established so sheet flow erosion is reduced. The stockpiling of native topsoil for reuse usually speeds up the re-stabilization process (U. S. Soil Conservation Service, 1991). Routine cleaning of storm sewers and mowing the vegetation in drainage swales (which includes removal of clippings) can reduce organic and nutrient loadings from decaying plant matter, as well as increase the nutrient uptake by the new growth. While use of the shortest possible flow path over paved areas (i.e. minimal curb and gutter lengths) resulted in more contaminants in highway runoff (Asplund, 1980), directing the runoff through grass swales showed significant improvements in water quality (Chui, 1981; Engomoen, 1985). Williams, *et al*. (1990) evaluated 500 vegetated buffer strips and found they reduced sediment loads by up to 90%, although they were not effective at reducing soluble nutrients or pesticides.

Oil and grease from fuel spills or aircraft maintenance can be contained by conducting fueling and maintenance operations in a centralized area, requiring the placement of absorbent "pigs" along the drainage path before any refueling or liquid line maintenance, or by revising the physical fueling connectors and procedures for localized collection of fluids during maintenance. These options are being considered separately by the air station staff. The preferred option for fuel spill control is the construction of a central hot fueling pit, but the same effect, from a spill control standpoint, could be obtained by simply restricting refueling operations to a specific parking area that drained into only one storm inlet. In this way, the cost of a structural solution to clean the spills would be greatly reduced. The nuisance to pilots and air crews, however, probably makes a centralized cold fueling location unacceptable.

BMPs for construction activities can be locally implemented. These include immediate replanting of finished grades, installation of silt fencing or sedimentation basins during construction, and the use of site layouts that leave wide buffer strips of native vegetation.

4.7 Storm Cleanup of Oil and Grease

The selection of a best possible structural solution to remove oil and grease from storm water depends on several operational constraints. These constraints include the availability of the land, utilities, trained personnel, and funds necessary to implement the plan and the technical capability to accommodate variable flows.

Horizontal land for water treatment facilities at an airport is often available between runways. However, airports have special constraints on vertical land use that may restrict which areas could accommodate above-ground structures. Therefore, one aspect of the land constraint is to maintain a low profile. A selected site must also have easy vehicle and worker access for maintenance.

Capital and operating costs must be considered. Annual Defense Appropriation Acts require that capital costs must be under $200,000 to allow local funding. Projects costing over $200,000 require Congressional authorization and appropriation, a process which can take five years. The cost of connecting electrical service or other utilities and operating pumps, compressors and other equipment must be evaluated. These costs are minimized in a process which uses gravity flow and no external aeration or mixing. Ideally, operating costs would be no higher than those currently expended.

A good system will be simple to understand, operate, maintain, and train others to operate. The operation of any system at Ault Field would use the same contractor personnel who currently remove the oily waste from behind the baffles. System effectiveness will be directly related to the simplicity and effectiveness of the maintenance program for the selected equipment.

The final, and most important, criterion is that the selected technique must remove the contaminant over the widest possible range of operating conditions.

There are several proven technologies for oil and grease removal. Dissolved air flotation, land application by spraying, air stripping and activated carbon adsorption have all been successfully used to treat various petroleum wastes. However, the design, construction and operation costs are also relatively high because of the requirements for pumps, tanks or other vessels, automation and monitoring, and utilities. Several useful technologies were considered in more detail. These included wetland creation, oil/water separators, sorbents, and mechanical skimmers.

4.7.1 Wetland Creation

Wetland creation is a land application technique which uses the natural assimilative capacity of plants, soil structure, chemistry and microbes to physically, chemically and biologically treat wastewater. The current storm water treatment, excluding the baffles, is essentially an operating wetland system. Wetland treatment counts on slow flows to allow settlement of suspended solids and heavy metals while the vegetation utilizes nutrients. Good removal of BOD, suspended solids, metals, nitrates and nutrients has been observed (Livingston, 1989; Watson, *et al.*, 1989). Water hyacinths are normally planted, although cattails (Dawson, 1989) and duckweed (Buddhavarapu and Hancock, 1991) work better in colder climates. Duckweed becomes dormant at 46^0 F and requires floating baffles to protect the plants from turbulent flows and wind. Cattails are already present at Ault Field, and would therefore make the better choice. Meiorin (1989) found that cattails remove metals better than bulrushes, although Livingston (1989) points out that the plant species that are most adaptable to the wetland loadings will eventually dominate.

Most constructed wetland experience, however, has been obtained in domestic wastewater applications and not storm water. Failure of constructed wetlands has been documented due to high settleable solids and oil and grease toxicity (Richardson and Daigger, 1984). It is not known if toxicity would be a problem at the current fuel concentrations, although the stained vegetation around the baffles (where the spills have been concentrated) is clearly dead. Nutrient removal in storm water applications varies widely since flows and seasonal fluctuations can alter the wetland biology and chemistry (Livingston, 1989). Additional complications include the requirement to harvest the plants during growing season, the existence of a dormant season that, in the case of Ault Field, coincides with the period of peak storm flows, and the inability to consume or trap nutrients quickly enough to cleanse a storm discharge. The fact that wetlands tend to attract birds and wildlife, one of their most beneficial advantages, is actually a detriment for airport facilities. Birds can be drawn into engine intake ports, causing substantial damage. In addition, the degree and significance of bioaccumulation in the food chain must be assessed. The inclusion of the drainage ditches on the Superfund list would complicate any such evaluation.

To be effective, constructed wetlands must generally be very large so the water remains relatively shallow (Allen, *et al.*, 1989). Results of a pilot study in Fremont, California, suggest that 50 to 80 acres would be required to accommodate flows at Ault Field (Meiorin, 1989). Costs for preparing a site this large could be prohibitive. The current draft of the Natural Resources Plan is proposing expanding existing wetlands by approximately three acres by widening the last 2,100 of dredged drainage ditch channel. If completed, the wetland outfall could be monitored to determine pollutant removal efficiencies and more accurately size a complete wetland treatment system.

4.7.2 Oil/Water Separator

The use of separators on storm flows is more complicated than process wastewater flows, since the volume and rate of water to be treated can vary so widely. The traditional method of separating floatable product from water is by using holding tanks with an oil dam and skimmer above a water outlet. Separation effectiveness depends on a low flow rate and high residence time (typically 2 to 4 hours), requiring very large tanks, and the oil concentration of recovered product varies depending on the concentration in the influent (Pushkarev, *et al.*, 1983). Designed to standards developed by the American Petroleum Institute (API), the separators can remove concentrations as low as 40 mg/L only if properly sized and maintained. Design is based on use of Stoke's Law of differential settling, and removal efficiency is reduced as solids and other impurities increase (Pushkarev, *et al.*, 1983).

Centrifugal separators have also been used for separation of oil and water. These introduce the water tangentially inside a cylinder or inverted cone. Lighter substances, like oil, accelerate slower and converge on the center, while heavier solids become more concentrated on the cylinder walls. The recovered oil tends to be high in water content, and the units do not work well with variable flows. Overall removal efficiencies are about the same as those of sedimentation units, but the detention time is shorter (Pushkarev, *et al.*, 1983). Their applicability to storm water flows at Ault Field is limited.

Coalescing plates can be added either vertically or horizontally to a separator to shorten the distance an oil droplet must travel before being removed from the water column. Facet Quantek (Tulsa, Oklahoma) produces corrugated coalescing plates spaced 1/4" or 1/2" apart. Water flows parallel to the horizontal corrugation, greatly reducing the travel distance of the oil, which collects in the higher portion of the corrugated plates and seeps upward through weep holes to the tank surface, where it is skimmed off. Facet Quantek reports three main advantages: the recovered oil has typically less than 5% water which allows for product recycling, the same size tank can handle flows four times greater than conventional API separators, and oil concentrations in effluent can be lowered to 15 mg/L. Design is dependent on the quantity of flow, suspended solids concentration, temperature range, and the properties of oil and water.

The initial cost of a separator and recovery tanks capable of handling an 800 gallon per minute flow from two, 60-inch concrete pipes would be approximately $30,000 (Leonard, 1991). Similarly sized equipment would need to be installed at two locations to prevent continued contamination of the baffle areas, and at least one location to prevent contamination from a spill on the runway itself. Routine maintenance would require periodic removal and cleaning of the coalescing plates, periodic sediment removal from the tanks, and recovery of the collected fuel. Controlling the growth of algae on the plates, which would reduce the flow capacity, could be a troublesome maintenance item. Bypasses must be installed to accommodate flows greater than the design capacity.

4.7.3 Sorbents

There are several types of products that are commercially available to absorb oil and grease. Organic sorbents include corn cobs, wood pulp or cotton fibers. Inorganic sorbents include modified clays or glass. Synthetic sorbents are usually constructed of polypropylene or polyethylene, which may be folded into sheets, chopped or sliced as filler material.

Organically modified clays, although originally used as stabilizers to minimize the leaching potential of hazardous wastes, have been shown to be very effective for oil and grease removal in water treatment processes (Alther, *et al.*, 1990). Unlike carbon adsorption, modified clays swell as organics are adsorbed. Eventually the adsorptive capacity is lost and the clay must be disposed of or regenerated. Brand names include Bentec Ecosorb, Calgon Klensorb 100, and Electrum Organosorb (Alther, *et al.*, 1990). The clays could be formulated to float on the surface of the drainage ditches, making the treatment effective across a wide range of flows. Volatile organics are not adsorbed well by clay, but metals are. The system could be coupled with other treatments to remove other contaminants.

Synthetic sorbents are more promising for the drainage ditch application because they are easier to handle. Lightweight and inexpensive, they can selectively adsorb oils only. Densely packed "sausage" booms can maintain their shape and not separate. The two main disadvantages, solar degradation and low strength, can be overcome by proper placement and design (Schrader, 1991). Installing two or three booms across the ditch at desired locations would permit adsorption of all but the largest spills. As their adsorptive capacity is used up they float lower in the water and become stained, but they can be recovered and replaced easily, with little regard for the wind. Waste disposal costs would be reduced by nearly 90%, since use of the oleophilic and hydrophobic sorbents means that water no longer requires hazardous waste disposal.

One manufacturer, Sorbent Products Company, claims their booms adsorb 10 to 25 times their weight in oil. Using the assumed 1990 recovery of 495 gallons (9 drums) of oil, a specific gravity of 0.8 would mean that about 3,370 pounds of oil were recovered with the existing system. This would require at least 337 pounds of sorbent at a cost of about $5 per pound, which indicates that sorbent material costs could be under $2,000 per year.

Lining the open ditch from the storm drain outlet to the sorbent location would prevent contamination of the drainage ditch. Ditch lining should be considered essential for any of the clean up options. A fence or grate would be necessary to hold the sorbents in place at each selected location. Placing the fence at an angle of less than 90^0 to the flow would maximize the amount of time available for the oil to transfer to the sorbent. Sorbent Products claims their booms do not photodegrade, but construction of a cover across the drainage ditches at the boom locations may be desirable as a means to avoid their disturbance from very high winds or jet blast. Maintenance costs would be similar to the existing system since weekly checking would still be necessary. Disposal costs, however, would be substantially lower.

4.7.4 Mechanical Skimmers

The existing baffle system is essentially a skimmer that isolates floatable product. The biggest deficiencies with the present system are its inability to prevent skimmed product from floating upstream and the ease with which collected product can overflow the baffle as storm water rises. The first problem can be overcome by installing an oil overflow weir so the oil, once trapped, is removed from the baffle area. This would require a small pump to lift the collected product from the drainage ditch area into a holding tank. The second problem could be corrected by converting to a floating instead of fixed baffle. Bypasses would then occur at only the highest flows, when the entire ditch is submerged.

Mechanical skimmers include the use of belt presses or rotating disks which adsorb oils as they pass through the water and release them as they pass through a squeegee or knife edge (Christodoulou, *et al.*, 1990). To be effective, they require a floating platform to control the depth the belt or skimmer penetrates, properly selected belt materials and storage facilities for the collected product.

McChord Air Force Base is using a belt skimmer separator system for storm water treatment from the flight lines. The most significant operational problem is that the recovered product is less than 10% oil. Effluent testing has not identified any NPDES violations, but ocean booms are in place across the discharge creek to stop any oil that escapes the skimmers. The booms would be overcome by any significant storm flows, however (Grenko, 1991).

4.8 Storm Cleanup of Total Suspended Solids

The tendency for suspended solids to adsorb and transport most pollutants makes their removal from the water column a desirable goal and a likely candidate for regulatory control. Oil/water separators and wetlands can remove suspended solids in addition to oil and grease. Skimmers and sorbents operate with little interference from suspended solids, but do not reduce the TSS concentrations. To remove TSS loads, only two principal options exist: sedimentation or filtration.

Filtering storm water through sand or synthetic membrane media would be very effective at removing pollutants. However, filtration of storm runoff would be prohibitively complicated and expensive due to the difficulty of backwashing the filters or replacing the membranes.

The most common structural improvement for storm water management is the use of detention ponds (Finnemore, 1982a). These may be unlined basins to allow infiltration, combined sewers with inline storage, or basins designed to hold a "first flush" of contaminants. The best designs have an outlet structure designed to allow deposition of settleable solids and release of storm flow at levels not to exceed the pre-development levels so downstream erosion is minimized. The biggest variable when choosing a structural improvement is the availability of land for the selected improvement (Finnemore, 1982a). Ault Field has significant open space in the general developed area and large open areas between the runways for possible structural improvements.

Studies in Montgomery County, Maryland, show sediment trap efficiencies of 96-99% for removing nine associated pollutants (BOD, COD, total organic carbon, ammonia, phosphorous, zinc, cadmium, lead and iron) (McCuen, 1978). Detention ponds in Orlando, Florida, reduced suspended solids and metals 42% to 66%, and nutrient removals varied between zero and 72% (Martin, 1988). To design a basin for a desired removal goal, a particle size and density analysis should be obtained for representative influent. Stoke's law can then be used to determine an adequate detention time.

One concern of sediment basins is that the bottom sediments may become so contaminated that they would be classified as hazardous wastes. Yousef and Lin (1990) conducted Toxicity Characteristic Leachate Procedure testing on the upper 10 to 20 cm of Florida highway detention basins that had been in operation between 4 and 13 years, and found that the sediments would not be classified as hazardous waste. While testing of sediments may be necessary, their identification as hazardous waste is not automatic.

4.9 Additional Research

To establish meaningful discharge standards, a better understanding of Dugualla Bay and the stilling basin hydraulics and background contaminants needs to be developed. The Superfund site characterization and Sajan, Inc. storm sewer studies now in progress should go a long way toward filling in the gaps in knowledge.

A full watershed land use inventory and storm drain system map are necessary to select the best locations for testing specific pollutants and developing effective control and management strategies.

Biological monitoring of Dugualla Bay and the stilling basin would be useful to identify if any of the suspected contaminants are actually damaging the environment. This would allow a monitoring program to be developed that actually attempts to identify and prevent environmental degradation, rather than just satisfy a statutory requirement.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Establish Accurate Flow Measurement

Sampling under the permit requires that flow be reported at the time of grab sampling and over the composite period. To do this, a flow discharge equation needs to be developed. If permanent composite sampling is required, a weir or flume and automatic flow measurement equipment should be installed.

5.2 Establish Appropriate Sampling Location

This permit is for an industrial storm water discharge, and selection of a sampling location must be designed to identify industrial pollutants. Sampling at the point of discharge to Dugualla Bay would include contaminants from non-Navy property. Flow estimation and sample compositing would be complicated by the dual discharge points of tide gate and pump outlet. Sampling at the property boundary or point of discharge to the meander would also include runoff from non-Navy property as well as Navy owned agricultural land, and site access would be difficult. Sampling at the present location records the flow from nearly all Navy land, but is at neither the property boundary nor the point of discharge to natural waters. Nonetheless, it is closest to the sources of industrial pollutants such as oil and grease and is the recommended sampling location for permit application and monitoring sampling. Once established as a permanent location, a tipping bucket rain gauge should be installed which can activate an automatic sampler or notify the individual responsible for sampling.

5.3 Test for Probable Pollutants

Testing for the probable pollutants in Table 6 should be conducted during the first storm of the season in order to allow the permit application to be submitted on time. The remote location of Ault Field and necessity for collecting the first sample within 30 minutes of the storm start requires that either a contractor be hired or civil servant be trained in appropriate sampling protocol.

5.4 Sample at Required Frequency

The air station, when applying for the permit extension, should recommend a change in sampling routine. Since the new regulations require sampling keyed to storm events, the air station should request reconsideration of the current weekly sampling requirement in favor of the qualifying event sampling frequency. While automatic sampling equipment would be required, the long-term cost savings could result in an overall savings. In addition, keying the sampling to storm events will provide a more realistic assessment of the total pollutant loadings to the receiving water.

5.5 Prevent Further Contamination of Baffle Area

Continuing practices which result in further contamination of the drainage ditches and baffle areas will result in continuing the risk of storm water pollutant discharges, complicate the characterization and cleanup of existing contamination, and subject the Navy to possible legal entanglements. Further contamination can be stopped by end-of-pipe or beginning-of-pipe controls.

5.5.1 Best Management Practices

Although treatment standards for the storm discharge may not be required under the terms of the renewed NPDES permit, good management requires that Best Management Practices be implemented where feasible. These beginning-of-pipe controls include the prevention of fuel spills by careful refueling and training, localized cleaning with sorbents instead of flushing spilled fuel with water, construction of a central aircraft hot-fueling facility, runoff controls from construction areas, and maintenance of the existing grass drainage swales in the urban areas.

5.5.2 Improve Baffle Operation

Installation of either coalescing plate separators or oil sorbent booms at the point of storm sewer discharge to the runway drainage ditches would remove any spilled fuel before contaminating the soil. Oil sorbent booms appear to be the most economical and require the least engineering. These locations, however, are also fresh water wetlands on the Superfund list and any construction that lines or excavates the channel could be administratively difficult. Until the site characterization is completed, sorbent booms could be installed at the existing first and second baffles to collect spilled product in lieu of the baffle and portable suction equipment. This would allow the skimmer booms to float at any water level, prevent collected fuels from being dispersed by the wind, reduce the opportunities for oil to sorb to the drainage ditch soils, and reduce hazardous waste disposal costs. In addition, it would allow the air station to evaluate the effectiveness of the adsorbents prior to installing them at other locations in the drainage ditches.

REFERENCES

Allen, Hollis H., Gary J. Pierce, and Rex Van Wormer. 1989. "Considerations and Techniques for Vegetation Establishment in Constructed Wetlands." Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural. ed. Donald A. Hammer. Lewis Publishers, Inc. Chelsea, Michigan. p. 405-15.

Alther, George R., Jeffrey C. Evans, and Stephen E. Pancoski. 1990. "No Feet of Clay." Civil Engineering, 60: October: 60-1.

Amy, Gary L., Roberto M. Narbaitz, and William J. Cooper. 1987. "Removing VOCs from Groundwater Containing Humic Substances by Means of Coupled Air Stripping and Adsorption." Journal of American Water Works Association, August: 49-54.

Asplund, Randy L. 1980. "Characterization of Highway Stormwater Runoff in Washington State." A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science, University of Washington, Seattle, WA.

Asplund, Randy L., John F. Ferguson, and Brian W. Mar. 1982. "Characterization of Highway Runoff in Washington State." Journal of Environmental Engineering, 108: 391-392.

Buddhavarapu, Lakshmi R., and Sean J. Hancock. 1991. "Advanced Treatment for Lagoons Using Duckweed." Water, Environment & Technology, 3: March: 41-4.

Callahan, Michael A., Michael W. Slimak, Norman W. Gabel, and others. 1979. Water-Related Environmental Fate of 129 Priority Pollutants, Volumes I and II. EPA-440/4-79-029a,b. U. S. Environmental Protection Agency, Office of Water Planning and Standards, Washington, D. C.

Christodoulou, M. S., J. T. Turner, and S. D. R. Wilson. 1990. "A Model for the Low to Moderate Speed Performance of the Rotating Disk Skimmer." Journal of Fluids Engineering, 112: 476-80.

Chui, Tai Wik David. 1981. "Highway Runoff in the State of Washington: Model Validation and Statistical Analysis." A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science, University of Washington, Seattle, WA.

Chui, Tai Wik, Brian W. Mar, and Richard B. Horner. 1982. "Pollutant Loading Model for Highway Runoff." Journal of Environmental Engineering, 108: 1193-210.

Clark, David L. 1980. "Composite Sampling of Highway Runoff." A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science, University of Washington, Seattle, WA.

Clark, David L., Randy L. Asplund, John F. Ferguson, and Brian W. Mar. 1981. "Composite Sampling of Highway Runoff." Journal of Environmental Engineering, 107: 1067-81.

Clewell, H. J., III. 1980. "USAF Final Report." ESL-TR-80-17. Journal of Aircraft, 20: 382.

Dawson, Bill. 1989. "High Hopes for Cattails." Civil Engineering, 59: May: 48-50.

Donigian, A. S. Jr., and N. H. Crawford. 1977. Simulation of Nutrient Loadings in Surface Runoff with the NPS Model. EPA-600/3-77-065 Hydrocomp, Inc. Palo Alto, CA

Eganhouse, R. P., B. R. T. Simoneit, and I. R. Kaplan. 1981. "Extractable Organic Matter in Urban Stormwater Runoff. 2. Molecular Characterization." Environmental Science and Technology, 15: 315-26.

Engomoen, Marc. 1985. "Stormwater Management Emphasizes Soft Improvements." Public Works, July: 66-7.

Federal Register. 6 April 1987. U. S. Environmental Protection Agency, 47:66.

Federal Register. 16 November 1990. U. S. Environmental Protection Agency, National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges; Final Rule.

Finnemore, E. John. 1982a. "Stormwater Pollution Control: Structural Measures." Journal of Environmental Engineering, 108: 706-21.

Finnemore, E. John. 1982b. "Stormwater Pollution Control: Best Management Practices." Journal of Environmental Engineering, 108: 835-51.

Ghiorse W. C., and D. L. Balkwill. 1983, "Enumeration and Morphological Characterization of Bacteria Indigenous to Subsurface Environments." Developments in Industrial Microbiology, 24: 213-224.

Grenko. Mike. 24 July 1991. Personal Communication. Environmetal Affairs Office, Base Civil Engineer, McChord Air Force Base, Tacoma, Washington.

Griffin, Mitchell, William Kreutzberger, and Peter Binney. 1991. "Research Needs for Nonpoint Source Impacts." Water, Environment & Technology, 3: June: 60-4.

Hawley, Besoner G. 1981. The Condensed Chemical Dictionary, Tenth Edition. Van Nostrand Reinhold Co., New York.

Kerr, James M. 1990. "Investigation and Remediation of VOCs in Soil and Groundwater." Environmental Science & Technology, 24: 172-3.

Lager, John A., William G. Smith, William G. Lynard, Robert M. Finn, and E. John Finnemore. 1977. Urban Stormwater Management and Technology: Update and Users' Guide. EPA-600/8-77-014. Metcalf & Eddy, Palo Alto, California.

Leonard, John R. July 1991. Personal Communication. Sales Associate, Northwest Power. Seattle, Washington.

Lindsay, Andrea. June 1991. Personal communication, NPDES Permitting, U. S. Environmental Protection Agency Region X, Seattle, WA.

Little, Lys M., Richard R. Horner, and Brian W. Mar. 1983. Assessment of Pollutant Loadings and Concentrations in Highway Storm Runoff. FHWA WA-RD-39.12.1. Report to Washington State Department of Transportation by Department of Civil Engineering, University of Washington, Seattle.

Liu, Zhongbao, Shonali Laha, and Richard G. Luthy. 1991. "Surfactant Solubilization of Polycyclic Aromatic Hydrocarbon Compounds in Soil-Water Suspensions." Water Science Technology, Kyoto, Japan. 23: 475-85.

Livingston, Eric H. 1989. "Use of Wetlands For Urban Stormwater Management." Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural. ed. Donald A. Hammer. Lewis Publishers. Inc. Chelsea, Michigan. p. 253-62.

Mar, Brian W., Richard R. Horner, Joanna S. Richey, Richard N. Palmer, and Dennis P. Lettenmaier. 1986. "Data Acquisition: Cost-Effective Methods for Obtaining Data on Water Quality." Environmental Science Technology, 20: 545-51.

Mar, Brian W., Wayne S. Mitter, Richard N. Palmer, and Richard. A. Carpenter. 1987. Cost Effective Data Acquisition: Guidelines for Surveying and Monitoring Watersheds. East-West Environment and Policy Institute, Workshop Report No. 1.

Martin, Edward H. 1988. "Effectiveness of an Urban Runoff Detention Pond-Wetlands System." Journal of Environmental Engineering, 114: 810-27.

McCabe, Mark M. 1989. "Waste Oil." Standard Handbook of Hazardous Waste Treatment and Disposal. Harry M. Freeman, ed. McGraw-Hill, Inc. New York. p. 4.3-12.

McCuen, Richard H. 1978. "On-Site Control of Nonpoint Source Pollution." Proceedings, Stormwater Management Model (SWMM) Users Group Meeting, EPA 600/9-79-003. U. S. Environmental Protection Agency, Washington, D.C. p.28-38.

McKinnon, Ronald J., and John E. Dyksen. 1984. "Removing Organics from Groundwater Through Aeration Plus GAC." American Water Works Association Journal, 76: 42-7.

McMoran, Don. 16 July 1991. Personal Communication. Farmer, Oak Harbor, Washington.

Meiorin, Emy Chan. 1989. "Urban Runoff Treatment in a Fresh/Brackish Water Marsh in Fremont, California." Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural. ed. Donald A. Hammer. Lewis Publishers, Inc. Chelsea, Michigan. p. 677-85.

Naval Energy and Environmental Support Activity (NEESA). 1984. Initial Assessment Study of Naval Air Station, Whidbey Island, Washington. Ed. Elizabeth B. Luecker. NEESA 13-055.

Palmer, Richard N., and Mary C. MacKenzie. 1985. Journal of Water Resources Planning and Management, 111: 478-93.

Patterson, James W. 1985. Industrial Wastewater Treatment Technology, Second Edition. Butterworth Publishers, Stoneham, Massachusettes.

Prendergast, John. 1991. "Privatization Takes Flight." Civil Engineering, 61: February: 37-39.

Puget Sound Water Quality Authority (PSWQA). 1988. State of the Sound 1988 Report. Seattle, WA.

Puget Sound Water Quality Authority (PSWQA). 21 November 1990. 1991 Puget Sound Water Quality Management Plan. Seattle, WA.

Pushkarev, V. V., A. G. Yuzhaninov, and S. K. Men. 1983. Treatment of Oil-Containing Wastewater. Allerton Press, New York.

Rathbun, Ronald E., and Doreen Y. Tai. 1982. "Volatilization of Organic Compounds from Streams." Journal of Environmental Engineering, 108: 973-89.

Reinelt, Lorin E., Richard R. Horner, and Brian W. Mar. 1988. "Nonpoint Source Pollution Monitoring Program Design." Journal of Water Resources Planning and Management, 114: 335-52.

Richardson, David L., and Glen T Daigger. 1984. "Aquaculture: The Hercules Experience." Journal of Environmental Engineering, 110: 949-60.

Robinson, Rita. 1988. "Space Age Pueblo." Civil Engineering, 58: April: 42-45.

Schrader, Ed L. 1991. "Testing Sorbent Booms for Oil Spill Cleanup." Pollution Engineering, 23:May: 72-75.

Schurr, LCDR Jim. 25 Apr 1991. Personal Communication. Environmental Affairs Office, NAS Whidbey Island.

SCS Engineers. 1988. Current Situation Report: Naval Air Station Whidbey Island, Washington. Pacific Northwest Branch Office, Western Division Naval Facilities Engineering Command, Silverdale, WA, N62474-85-C-0749.

Southworth, George R., Stephen E. Herbes, and Carol P. Allen. 1983. "Evaluating a Mass Transfer Model for the Dissolution of Organics from Oil Films into Water." Water Research, 17: 1647-51.

Stenstrom, Michael K., Gary S. Silverman, and Tara A. Bursztynsky. 1984. "Oil and Grease in Urban Stormwaters." Journal of Environmental Engineering, 110: 58-72.

Tchobanoglous George, and Frank Burton. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse, 3rd edition. Metcalf & Eddy, Inc. McGraw-Hill, New York.

Tener, Diana. 25 April 1991. Personal Communication. Evironmental Affairs Office. NAS Whidbey Island, Washington.

U. S. Soil Conservation Service. 1991. Natural Resources Management Plan - NAS Whidbey Island, 1991 (DRAFT).

U. S. Environmental Protection Agency (USEPA). 1988. Water Quality Standards Criteria Summaries: A Compilation of State/Federal Criteria. EPA-440/5-88/005-007,011-013, and 015-030. Office of Water Regulations and Standards, Washington, D. C.

U. S. Environmental Protection Agency (USEPA). 1986. Water Quality Criteria Summary. EPA-440/5-86/001. Office of Water Regulations and Standards, Washington, D. C.

Watson, James T., Sherwood C. Reed, Robert H. Kadlec, Robert L. Knight, and Alfred E. Whitehouse. 1989. "Performance Expectations and Loading Rates for Constructed Wetlands." Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural. ed. Donald A. Hammer. Lewis Publishers, Inc. Chelsea, Michigan. p. 319-51.

Weast, Robert C., ed. 1989. CRC Handbook of Chemistry and Physics, 70th Edition. CRC Press, Inc. Boca Raton, Florida.

Welch, Eugene B. 1980. Ecological Effects of Waste Water. Cambridge University Press, New York.

White R. E. 1979. Introduction to the Principles and Practice of Soil Science, Blackwell Scientific Publications, Oxford, England.

Williams R. D, A.D. Nicks, and J. N. Krider. 1990. "Evaluation of Vegetative Filter Strips as a Management Practice for Non-point Source Pollution." Proceedings of the 1990 Specialty Conference on Environmental Engineering. ed. Charles R. O'Melia. American Society of Civil Engineers. New York. p. 799-806.

Wu, Shian-Chee, and Philip M. Gschwend. 1986. "Sorption Kinetics of Hydrophobic Organic Compounds to Natural Sediments and Soils." Environmental Science Technology, 20: 717-725.

Yousef, Yousef A., and L. Yu Lin. 1990. "Toxicity of Bottom Sediments in Detention Ponds." Proceedings of the 1990 Specialty Conference on Environmental Engineering. ed. Charles R. O'Melia. American Society of Civil Engineers. New York. p. 809-16.

Zison, S. W. 1980. Sediment-Pollutant Relationships in Runoff from Selected Agricultural, Suburban and Urban Watersheds, a Statistical Correleation Study. EPA-600/3-80-032 Tetra Tech, Inc. Lafayette, CA.

APPENDIX

Precipitation Event Summary Data, 1984-1989.

1989

Month	Precip (in)	Days >0.10 in	Days >0.50 in	Qualifying Events
January	3.38	11	2	5
February	2.04	7	1	1
March	2.98	10	0	4
April	1.02	4	1	3
May	2.16	6	2	3
June	.26	1	0	1
July	.50	2	0	2
August	1.30	3	1	2
September	.15	1	0	1
October	1.41	6	0	3
November	4.01	11	1	4
December	1.36	4	1	2
Totals	20.57	66	9	31

1988

Month	Precip (in)	Days >0.10 in	Days >0.50 in	Qualifying Events
January	1.26	5	0	2
February	.56	1	0	1
March	2.69	8	1	4
April	2.78	9	1	2
May	2.01	5	2	4
June	1.03	3	1	1
July	.65	3	0	3
August	.38	1	0	1
September	.68	3	0	1
October	1.83	6	1	3
November	1.86	8	0	3
December	2.38	10	1	4
Totals	18.11	62	7	29

1987

Month	Precip (in)	Days >0.10 in	Days >0.50 in	Qualifying Events
January	2.37	10	0	4
February	1.27	2	1	3
March	1.17	3	0	3
April	1.23	4	0	2
May	.80	2	0	1
June	.20	0	0	0
July	.73	3	0	2
August	.40	1	0	1
September	.68	2	0	1
October	.08	0	0	0
November	1.40	4	0	2
December	2.89	9	2	3
Totals	13.22	40	3	22

1986

Month	Precip (in)	Days >0.10 in	Days >0.50 in	Qualifying Events
January	1.51	6	0	3
February	2.03	6	1	4
March	.94	3	0	3
April	1.51	6	0	4
May	1.83	7	1	4
June	1.05	5	0	1
July	.97	4	0	3
August	.06	0	0	0
September	1.38	5	0	3
October	.88	2	1	1
November	3.98	12	2	4
December	.91	2	0	2
Totals	17.05	58	5	32

1985

Month	Precip (in)	Days >0.10 in	Days >0.50 in	Qualifying Events
January	.34	2	0	2
February	1.76	8	0	6
March	1.49	7	0	3
April	.91	4	0	2
May	1.31	5	0	4
June	1.33	4	1	1
July	.14	1	0	1
August	.53	1	0	1
September	1.04	4	0	2
October	4.17	12	3	2
November	2.82	12	0	4
December	.50	3	0	1
Totals	16.34	63	4	29

1984

Month	Precip (in)	Days >0.10 in	Days >0.50 in	Qualifying Events
January	2.75	8	1	2
February	2.72	6	2	3
March	2.02	5	1	3
April	.96	4	0	3
May	3.55	8	2	3
June	2.61	5	1	4
July	.02	0	0	0
August	.86	3	1	3
September	2.43	4	2	2
October	1.68	7	1	4
November	3.22	12	0	4
December	2.84	9	1	2
Totals	25.66	71	12	33